NUCLEAR ENGINEERING VOL. 3 NO. 30 SEPTEMBER, 1958

Science to Commerce

THREE years have now elapsed since the dramatic International Conference on the Peaceful Uses of Atomic Energy in 1955, when for the first time scientists and engineers from all over the world were allowed to come together to discuss openly their findings and their current projects. The success of that Conference was overwhelming and the political and psychological impact can never be repeated.

In the ensuing years a great change has come over the whole scene of nuclear engineering. Atomic energy is no longer the province of the theoretical investigator, nor is it merely the hunting ground of the prototype designer. Atomic energy is now commerce, and big commerce at that. Three years ago commercial designs were in the drawing-board stage only and many of the parameters upon which these designs were based, both scientific and economic, were questionable. Today in the United Kingdom there are four nuclear power stations under construction. The first three are expected to produce electricity at a cost only slightly above that obtained from modern stations burning coal, whereas the fourth is expected to give a generating cost slightly lower than the projected average cost from conventional sources. In this issue we publish articles by leaders of the main industrial reactor design teams which detail the constitution of the teams and outline the broad developmental approach.

More Realistic Attitude

The past three years have seen many important power projects come to fruition; Calder Hall, the Nautilus, Shippingport, EBWR and now G2 with the research and experimental facilities of the more advanced nations greatly increased and similar facilities being set up in an ever-widening circle of countries around the globe. The period has been one of excitement and one of drama, but of more importance is the growth of realism and the heightened appreciation of the problems that are involved. Atomic energy in 1955 was an emotional subject and even on purely technical subjects the realm of fantasy was not far away. Perhaps worse, the mirror of politics was always likely to introduce a distorting factor. This has not yet been eliminated but is progressively giving way to a more wholesome pride in achievement with a willingness to give credit where it is due. No longer, also, do we speak of atomic energy as the universal panacea and discuss under-developed countries as if the acquisition of two nuclear scientists were sufficient to bridge five generations of industrial development. Economics are no longer an academic exercise but concern hard cash—at least with the systems that have been built and proved.

We have yet to see, in the 1958 Geneva, whether the hard lessons that have been learnt over the past two or three years in the large power-station field have been fully applied to the small reactors suitable for, say, ship propulsion. There are certain indications that this is not the case. Also we have yet to see whether emotionalism can be completely excluded from the discussions on thermo-nuclear work which will undoubtedly attract a very wide interest both from the scientists and the non-technical public.

Geneva will see again a vast conclave of eminent nuclear scientists and engineers and if the total number of papers to be presented is anything to go by, an enormous amount of new information will be released. It is difficult to believe that all these papers will be of the same quality and will be based on hard scientific fact or experience, and there is a grave danger that much that is valuable will be submerged under a flood of trivialities. To mitigate this, *Nuclear Engineering* is assembling at Geneva a team of experts who will prepare for the October issue a summary (with references) of the most important disclosures. It would be unwise, however, and unjust to pre-judge the Conference and we can be sure that the personal meetings that will take place, the re-establishment of friendships, the informal exchange of views will all advance the technology of atomic energy and improve international relations.

It is, perhaps, in the exhibitions that the change in the state of atomic energy developments will be most immediately obvious and in the Palais des Expositions the large-scale and widespread industrial effort (particularly in the U.K.) can be appreciated. Geneva will see for the first time an international, commercial exhibition on atomic energy, with many examples of industrial design and industrial development on view. We in Britain can be proud of our part in this and of the scope and scale so demonstrated.

The Nautilus Saga

THE epic voyage of the U.S.S. Nautilus which was followed so closely by a similar voyage of the Skate has captured the imagination of the Western World. Apart from representing a remarkable feat of navigation, the journey has indisputably demonstrated the reliability of the Nautilus propulsion unit and the capacity of the submarine to travel for thousands of miles under water at high speed.

It is difficult at this time to assess the commercial significance of this voyage, but it will undoubtedly stimulate consideration of the large submarine merchant vessel only possible with a nuclear propulsion unit. Theoretically, at least, the submarine is more economical in terms of power consumption, and is capable is higher maximum speeds (*Nuclear Engineering*, Dec., 1957, p. 499), but the practical difficulties of operation are large. Mitchell Engineering have recently emphasized their interest in such a project by placing a contract with Saunders-Roe for a detailed feasibility study following tank tests which have been conducted over the past year. The company mentions specifically the advantages of the submarine cargo vessel in shipping ore from the Hudson Bay (normally closed for many months of the year) to the United Kingdom, but such applications are, perhaps, too specialized to justify the great development effort necessary. For tanker work the " submerged barge " may prove more economically attractive.

Irrespective, however, of eventual commercial developments, the exploits of the American submarines serve to give confidence in the reliability and flexibility of nuclear power generation, whilst the enthusiatic reception accorded the Nautilus, its captain and its crew in Portland by large crowds of holiday makers, shows the extent to which any initial mistrust of nuclear units has disappeared. Certainly, on its entrance into Portland, the area could not be described as thinly populated, and if the first visits to Portland and Plymouth did not establish a precedent in locating a nuclear power unit in a busy area, then this most recent visit certainly has. At some time, without question, international laws must be established to govern the sailings in peace time of even naval vessels, but in the meantime let us hope that the Nautilus will continue to blaze its trail of confidence across the world.

Plutonium from Civilian Reactors

THE decision of the Government to modify certain of the nuclear power stations under construction or projected in the United Kingdom to permit extraction of military grade plutonium has created a certain amount of misunderstanding and not a little disquiet. The first point that should be emphasized is that this is an enabling measure, and does not necessarily imply that the option will be exercised. Anticipated demands are continually altering and are subject to the varying political climate and the changeable opinions of the military experts. It is only prudent, therefore, that the Government should make its plans accordingly. But, even assuming that the move represents an intention rather than an insurance, there is no reason at present for suggesting that the civilian power programme will be in any way adversely affected nor, on the other hand, that military usage would represent a hidden subsidy for civilian power. Additional costs to provide the necessary facilities for the extraction of military plutonium will be borne by the military authorities, but only the additional costs; the generating authorities do not expect to receive any financial assistance for electricity generation.

If the modifications involved the optimization for plutonium production as against power production, then this should be regarded as a retrogressive step, but no such intention exists at present and the modifications involve only the provision of additional fuel-handling equipment both for charge and discharge of the reactor and for fuel preparation; these facilities being integral with the biological shield structure require, however, a re-design which is by no means insignificant. For cooling of the fuel elements after they have been irradiated storage on site has, in the main, been generously provided and no additional pond capacity will be required.

In view of the high conversion factor of the gas-cooled graphite-moderated reactor, even when optimized for power production, and the facility with which the reactor can be charged and discharged under load, it is perhaps more surprising that the military and civilian programmes have remained divorced for so long. The firm division stemmed originally from doubts about the continuity of supplies of uranium, and demonstrated the Government's determination that civilian developments should not be hampered by these doubts. Power programmes could thus be established which were not subject to military demands that might jeopardize fuel availability. The great change that has gone on over the past few years in uranium mining and extraction has altered this picture completely. Uranium is plentiful and, however short an irradiation time the military authorities demand, there is no possibility of power-station replacement fuel being short.

The U.K. nuclear power programme is now too large and too well-founded for any serious doubts to be cast upon its civilian motives. If our prestige suffers as a result of the Government ruling, then it is not so much the decision as the method of presentation that must be criticized. From a domestic point of view, although there are those who regard any interference by the military as the thin end of a disagreeable wedge, until there is real evidence that the generating authorities are being coerced by the military authorities in their planning or in their operation, there should be no cause for alarm

DIGEST...

Surveying Significant News

The Geneva Conference and Exhibitions

The Second International Conference on the Peaceful Uses of Atomic Energy opens in Geneva on September 1 and will continue for a fortnight. The scientific Conference to which over 2,300 papers have been submitted (not all will be presented) will be accompanied by two exhibitions. The United Nations exhibition held at the Palais des Nations will be supported by 21 countries and the commercial exhibition organized by the Swiss authorities at the Palais des Expositions will contain exhibits from 350 companies representing 13 nations. The Conference ends on September 13 and the commercial exhibition closes the following day.

Sub-polar Transit by Nautilus

Nautilus, the first nuclear powered submarine, has pioneered a new trans-polar route under the ice. Leaving Honolulu at 06.00 July 23 she dived under pack ice off Point Barrow at 12.37 August 1, passed under the North Pole at 03.15 August 4 and surfaced between Greenland and Spitzbergen at 13.54 August 5. This entailed travelling 1,830 miles under the ice in 96 hours. The Nautilus docked in Portland at 13.35 August 12, where commander and crew received tremendous ovation. Route established by Nautilus quickly followed by Skate which surfaced 40 miles from the Pole before continuing journey.

G2 Critical

G2 at Marcoule in France diverged on July 21 with a loading of 22.5 tonnes natural uranium as against the 22.3 calculated. Reactor is at present running at low power unpressurized and without cooling. Final loading will comprise 115 tonnes uranium in 36,000 fuel elements, each 30 cm. long arranged in 1,200 horizontal coolant channels within the graphite pile to form a core 8.45 m long by 7.8 m diameter. Commissioning experiments are under way and the full power of 150 MW (thermal) generating 40 MW electricity should be achieved by the end of the year. Construction of G2 was begun in November, 1955.

U.S.A.E.C. New Construction Allocation

Congress has authorized the spending of $386,679,000 in new nuclear construction in spite of Presidential opposition. The sum includes $145 M for a plutonium production installation at Hanford, suitable for conversion to electricity production at a later date if desired, $39 M for new physical research facilities for the Commission and $51 M for a gas-cooled, graphite-moderated enriched power reactor. It is now understood that this reactor will be helium cooled, similar to the ORNL GCR-2 Study described in *Nuclear Engineering*, July, 1958.

O.E.E.C. to Collaborate on H.T.G.C.

Plans should be finalized in September for O.E.E.C. collaboration in the H.T.G.C. reactor project at Winfrith Heath. The homogeneous aqueous reactor is not at present considered suitable for a major research and development effort, either by the A.E.A. alone or under a joint programme.

U.S.—U.K. Agreement Now in Force

The Anglo-U.S. agreement on the exchange of information of a military character which also included provision for the purchase of a submarine propulsion unit took effect from the beginning of August. Congress remained in session long enough for the necessary thirty days to expire and no objections were raised.

B.N.E.C. Incorporates Marine Societies

B.N.E.C. has increased its membership to nine constituent bodies by the addition of the Joint Panel on Nuclear Marine Propulsion. This comprises the Institute of Marine Engineers, the Institution of Naval Architects, the Institution of Engineers and Shipbuilders in Scotland and the North East Coast Institution of Engineers and Shipbuilders. Previous B.N.E.C. membership consisted of the Institutions of Civil, Mechanical, Electrical and Chemical Engineers; the Institutes of Physics, Metals and Fuel and the Iron and Steel Institute.

A.E.A.—P.R.D.C. Exchange Agreement

The A.E.A. concluded an agreement at the beginning of August with the Power Reactor Development Company of Detroit, U.S.A., for the exchange of information concerning the development of fast reactors. The agreement is for five years and comes into operation on October 1. PRDC is currently constructing the Enrico Fermi Nuclear Power Station (see *Nuclear Engineering*, March, 1957, p. 112) at Lagoona Beach, Monroe, Michigan. Full co-operation between the designers and operators of EBR-1 and 2, DFR and the PRDC plant is clearly desirable and it is to be hoped that much of the commercial security surrounding fast reactor work can now be dispensed with.

U.N. Radiation Damage Report

The report of the United Nations Scientific Committee on the effects of atomic radiation has now been published. As expected, the conclusions follow closely the reports previously drawn up by the U.S.A.E.C. and by the Medical Research Council of the U.K., both of which were published in 1956. The increase in radiation levels produced by the peaceful developments of atomic energy are shown to be negligible and the increased background from nuclear test explosions is also shown to be small in comparison with the diagnostic use of X-rays. Apart from specific accidents, and the records of existing establishments indicate that these are lower in number than in most heavy engineering industries, the increased hazard arising from peaceful atomic energy developments can be said to be zero.

M.o.P. Authorizes Trawsfynydd Station

The Ministry of Power has authorized the construction of a 400-500 MW nuclear station at Trawsfynydd in North Wales. This will be the fourth nuclear station to be built by the C.E.G.B. and tenders will be considered in the spring of next year. The site is adjacent to the Maentwrog hydro-electric installation which could provide pumped storage facilities.

SENN Decision at Geneva

Final report of the panel of experts examining tenders for the ENSI project in Italy has been passed to the International Bank for Reconstruction and Development and Professor Matteini, President of SENN. Final decision will be taken by Prof. Ippolito for the Italian Government and Mr. Allardice of I.B.R.D. This will be announced at the Geneva Conference and it is expected, following the awarding of the contract and completion of final agreements, that work can begin in the autumn.

J.A.P.C. Tenders In

Deadline for tenders to the Japan Atomic Power Company for a 150 MW earthquake-proof Calder type power station was July 31 and the proposals put forward by the three groups, G.E.C. Simon-Carves, English Electric—Babcock and Wilcox—Taylor Woodrow, and A.E.I.—John Thompson, are at present under consideration; the U.K.A.E.A. is expected to assist in the tender examination. A letter of intent to purchase will probably be sent in October and a similar letter of intent to purchase fuel will also be executed. Preliminary fuel contract will accompany building contract and final fuel terms will be concluded with A.E.A. one year before delivery.

Euratom not to Stock-pile Uranium

Euratom is not proposing to stock-pile uranium according to a communique following a meeting of the Council of Ministers recently. World supplies are considered entirely adequate and in view of probable further decreases in cost stock-piling would be an uneconomic measure. The same meeting discussed further plans for a nuclear research centre which is now to be equipped with an EM separator and a central measurements bureau.

I.A.E.A. First Report

First report of I.A.E.A.'s eight month activities will be submitted to the second session of the General Conference convened in Vienna for September 22. The report will discuss supply of fissionable material (no requests for which have yet been received by the Agency), technical assistance, including views on the need to establish one or more training centres in Latin America, the exchange of scientists and experts' technical information, health and safety and waste disposal, isotopes and research and international co-ordination.

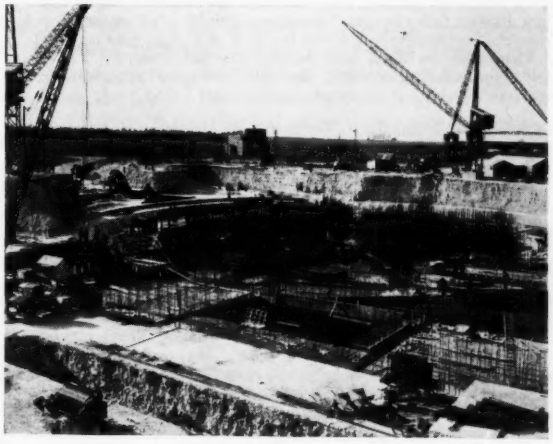
Reactor News in Brief

G2, the 150 MW (H) gas-cooled graphite-moderated reactor at Marcoule diverged on July 21. . . . The 50 kW solution-type research reactor supplied by Atomics Int. to West Berlin Institute for Nuclear Research commenced operating on July 24. . . . ALPR, Argonne's 3 MW (H) prototype BWR for remote military locations went critical on August 11. . . . TRIGA, General Dynamics 10-30 kW ZrH-moderated research reactor for Geneva exhibition diverged on August 7. . . .

N.I.R.N.S.

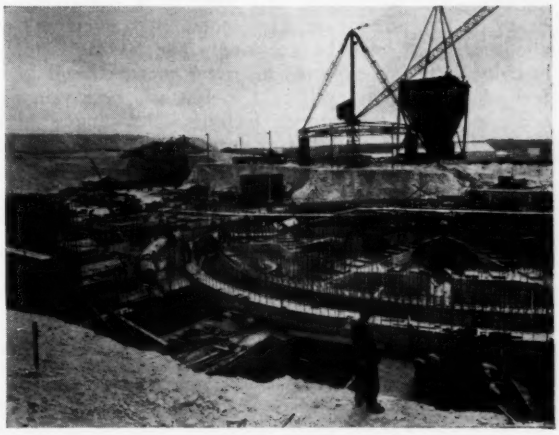
The Constitution, Objects, and Progress of the National Institute for Research in Nuclear Science

RECOGNIZING the great cost of advanced equipment for research into the nuclear sciences beyond the means of an individual university or institution, the Government decided to establish in the United Kingdom a national institute to provide facilities for common use. Although already associated with the CERN organization, it was felt that if fundamental research into physics was to be kept vigorously alive in the Universities a home laboratory was essential. Accordingly, in February, 1957, it was announced that the National Institute for Research in Nuclear Science would be set up and the following month the constituent representatives were published. These comprise, under the chairmanship of the Right Hon. Lord Bridges, seven representatives of the Universities, two from the University Grants Committee, one from the Royal Society, three from the Atomic Energy Authority and two from the Department of Scientific and Industrial Research. As the Institute is not merely to be an advisory body but will own property and will make decisions for which legal liability must be accepted, some method of incorporation was necessary and a Royal Charter was approved by the Queen in May of this year.



The 7 GeV proton synchrotron site showing the reinforcement.

The terms of reference of the Institute are wide. Clearly, research into high energy physics will occupy a considerable proportion of the Institute's time for some years to come, but research on, or using, reactors is not excluded. Nor for that matter are other large-scale tools of the physicist. For convenience only, the Institute is financed from the Treasury through the Atomic Energy Authority under a separate sub-head of the Atomic Energy Vote. This is essentially an administrative procedure rather than an implication that the Institute is in any way dependent for finances directly upon the Authority. At the same time, services provided by the A.E.A. to the Institute will be charged to this sub-head so that the finances of the Institute are not obscured by hidden subsidies. To assist in the organization, the Institute has set up three committees, a physics committee, a research reactor and a visiting committee, which include in addition to members of the Institute some outside senior scientists, and a general purposes committee, comprising only members of the Institute.



The 7 GeV proton synchrotron under construction.

Prior to 1957, Harwell had undertaken a feasibility study of a 600 MeV proton linear accelerator conscious of the fact that the Universities would wish to participate in its eventual use as well as the Authority's staff. Such an accelerator can be conveniently built up in stages and work was commenced on a 50 MeV section. In the meantime, experiments in the U.S.A. had shown that the yield of heavy mesons from a 3 GeV machine was much higher than expected, and had also demonstrated considerable improvements in beam extraction efficiency from circular accelerators; a basic attraction of the linear machine is the elimination of this problem. The threshold energy for the production of strange particles and anti-nucleons is approximately 6 GeV and therefore there was a strong incentive to reconsider the 600 MeV linear machine in favour of a 7 GeV circular machine.

The Institute on its formation was able to benefit from these previous studies and the A.E.A. offered to make available the 50 MeV proton linear accelerator to the Institute on its completion in April, 1959, and in addition to provide land suitable for development alongside A.E.R.E. and close to the site of this accelerator. Both these offers were accepted by the Institute and it was decided to establish the first laboratory, to be called the Rutherford High

Energy Laboratory, at Harwell; Dr. T. G. Pickavance has been appointed its Director.

The Institute decided that a 7 GeV proton synchrotron offered the best compromise between peak energy and beam current, consistent with a reasonable budget, and ground was broken for such a machine in July, 1957. With Chivers acting as main civil contractors and Mertz and McLellan as consultants, excavation of the site is complete and the concrete walls of the main structure are rising rapidly. A major contract for the magnet yoke was placed with Joseph Sankey last October and other important long-term contracts are now merely awaiting signature. The synchrotron will comprise a ring-shaped magnet 150 ft in diameter weighing 7,000 tons. Protons will be injected from a subsidiary 15 MeV accelerator and will be accelerated by an RF field, the magnetic field being phased to maintain a constant path. The chief difference in concept between this accelerator and the CERN machine, apart from size, lies in the focusing. For the 25 GeV CERN accelerator, strong focusing which automatically implies a narrow area beam is essential, but at lower energies economic forces are less exacting and a weak focusing system has been selected with a large beam area and, as a result, higher beam current. It is anticipated that when fully operational a beam of 10^{12} protons/sec, corresponding to a current of about 1/10 μA, will be achieved. The 50 MeV linear machine, which is expected to give a mean current of a few μA with a duty cycle of 1 in 100, will be a valuable addition to the laboratory's facilities, providing a high beam current at a peak energy corresponding to a field of research which has been somewhat neglected in the past.

The construction of the machine has been made the responsibility of the A.E.A. This again does not imply that the Authority will have a dominant control of operation, but the A.E.A. has built up a considerable experience in the technologies involved and can provide established design and constructional facilities. The A.E.A. will continue to provide administrative (including contractual) and engineering services to the laboratory, but operation will be the responsibility of the Institute. At present the permanent staff is small in number and its operational size has not been established yet, it being deemed better to gain experience in the detailed organization necessary rather than establish at the outset a rigid formula. A regular team of operators and of research personnel will clearly be necessary in order to run the machine and maintain it, to introduce newcomers to the techniques and to ensure that the machine is run with optimum usefulness. The term optimum can clearly be interpreted in a number of ways but present philosophy leans firmly towards providing the maximum facilities for those who wish to use it, rather than organizing for maximum speed of development along a particular line of research. One of the main responsibilities of the Director of the establishment will be to ensure a balanced use and to encourage the Universities to send people to perform experiments.

N.I.R.N.S. provides an opportunity for the Universities to maintain their standards in a field of research that was rapidly becoming beyond their pocket and the Rutherford Laboratories should do much to raise the standard of research in this country, not merely in high energy physics but in all branches of the natural sciences.

L'Institut National de Recherches dans la Science Nucléaire (N.I.R.N.S.)

L'Institut National de Recherches dans la Science Nucléaire a été établi en vue de fournir des facilités centrales aux universités et autres institutions désireuses d'entreprendre des recherches dans la physique de haute énergie. Les premiers laboratoires de l'Institut se trouvent à Harwell à côté del'Etablissement de Recherches de l'Energie Atomique (A.E.R.E.) et ont été surnommés les laboratoires " Rutherford " de Haute Energie. Un accélérateur linéaire de protons 50 MeV construit par l'Autorité de l'Energie Atomique du Royaume-Uni (U.K.A.E.A.) sera remis à l'Institut au mois d'Avril de l'année prochaine. Un synchrotron de protons 7 GeV qui sera la principale machine de l'Institut est en voie de construction.

N.I.R.N.S.—Das national Atomkern-Forschungs-Institut

Das nationale Institut für die Atomkern-Forschung ist eingerichtet worden, um ein Zentrum für solche Forschungen für Universitäten und andere Institute zu schaffen, die Forschungen auf dem Gebiet der Hochenergie-Physik durchzuführen beabsichtigen. Die ersten Laboratorien des Institutes befinden sich in Harwell neben der A.E.R.E; sie haben den Namen „ Rutherford High Energy Laboratories " erhalten. Ein 50 MeV geradliniger Protonen-Beschleuniger, der von der U.K.A.E.A. gebaut ist, wird nächstes Jahr im April dem Institut übergeben werden. Ein 7 GeV Protonen-Synchrotron, das die wichtigste Maschine des Institutes werden soll, ist unter Konstruktion.

N.I.R.N.S.—El Instituto Nacional de Investigación en la Ciencia Nuclear

El Instituto Nacional de Investigación en la Ciencia Nuclear ha sido establecido para proveer facilidades centralizadas a las Universidades y a las otras instituciones que desean llevar a cabo investigaciones en la física de alta energía. Los primeros laboratorios del Instituto están situados en Harwell, al lado del A.E.R.E. (Establecimiento de Investigaciones de Energía Atómica), y se les ha llamado los Laboratorios Rutherford de Alta Energía. En Abril del año próximo se entregará al Instituto un acelerador linear de protones de 50 MeV. construído por la U.K.A.E.A. (Autoridad de Energía Atómica del Reino Unido). Un sincrotono de protones de 7 GeV., que será la principal máquina del Instituto está en vía de construcción.

The Nuclear Power Plant Co., Ltd. (page 369)

La Nuclear Power Plant Company qui, en plus d'avoir construit la centrale d'énergie nucléaire de Bradwell s'est associée à l'AGIP Nucleare dans un projet de centrale d'énergie refroidie au gaz et modérée au graphite en Italie, se compose de neuf sociétés, chacune d'elles possédant une expérience spécialisée des techniques s'appliquant directement à la conception et la construction des centrales nucléaires. On y traite de l'organisation de la compagnie et dans l'article l'accent se porte sur le besoin d'une collaboration des plus étroites entre les ingénieurs civils, les ingénieurs-mécaniciens, les métallurgistes, etc.

Die Nuclear Power Plant Co. Ltd., die ausser dem Bau des Atom-Kraftwerkes in Bradwell auch mit der AGIP Nucleare zusammen an dem Projekt eines gas-gekühlten mit Graphit als Bremsstoff geplanten Kraftwerkes in Italien arbeitet, setzt sich aus neun Gesellschaften zusammen, die jede spezielle Erfahrungen auf Gebieten der Technik hat, die direkt im Entwurf und Bau von Atom-Kraftwerken anwendbar sind. Es wird die Organisation der Gesellschaft besprochen und die Bedeutung für engste Zusammenarbeit zwischen Bauingenieur, Maschinenbauer, Metallurgen usw. hervorgehoben.

La Nuclear Power Plant Company que, además de construir la central de fuerza nuclear de Bradwell, está asociada con AGIP Nucleare en un proyecto de una central de fuerza con enfriamiento por gas y moderación por grafito en Italia, comprende nueve compañías, cada una con experiencia especializada en técnicas directamente aplicables al diseño y a la construcción de centrales nucleares. Se discute la organización de la Compañía y se pone énfasis en la necesidad de la más estrecha cooperación entre ingenieros civiles, ingenieros mecánicos, metalurgos, etc.

Reactor Exports and the U.K.A.E.A.

Liaison with Industry in Overseas Markets

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THE 1955 U.K. programme announced a few months before the first Geneva Conference, envisaged the construction in the U.K. by 1965 of sufficient nuclear civil power stations to provide 1,500 to 2,000 MW of electricity. Since that time the success of Calder Hall has been proved beyond all doubt and this together with two further factors led to a re-assessment of the original programme.

In the first place, the rapid advances in technology which had been made in the intervening period enabled reactors to be designed having four times the electrical output of the first Calder reactor. Secondly, the electricity stations in this country were burning 40/45 million tons of coal a year and in a further 12 years' time this figure would have been doubled. It was not possible for this fuel to be made available in the U.K. and without greater use of nuclear power the only alternative would have been an increasing dependence on imported fuel—mainly oil.

Because of these considerations the Government announced in 1957 a revised programme providing for some 19 power stations to be commissioned by 1965 and providing in total a capacity of 5,000-6,000 MW(E). Even since this announcement, further advances in technology have been made enabling the design of reactors having six times the electrical output of Calder and this in practice will mean that fewer than the 19 power stations will be required to provide the 6,000 MW.

This trebling of the original programme will necessitate an additional capital investment of some £750m. beyond that which would have been required for a purely conventional programme. When this is considered against the background of the U.K.'s already extensive national investment programme, the magnitude of this nuclear plan emphasizes the confidence of the U.K. in the Calder type reactor.

It was in 1954 that the potential of the Calder type reactor for civil application was first appreciated, encouraging British industry to prepare itself for the new techniques which would be involved. As a result several groups of companies formed themselves into consortia, each consortium consisting of specialists having complementary interests and experience in the conventional power station field.

This combination of knowledge, backed up by early training and subsequent collaboration with the U.K.A.E.A., has ensured that British industry is fully equipped to deal with all inquiries for the complete design, construction and commissioning of nuclear power stations both in the U.K. and overseas.

The Authority's Rôle

Working in parallel with the British firms, the U.K.A.E.A. is able to supply and reprocess the natural uranium fuel for the operation of these stations. In addition the Authority is also involved in providing the nuclear graphite used in these reactors.

The Authority's rôle in peaceful developments lies principally in three directions. The first, and perhaps foremost, is to ensure that research effort commensurate to the importance of the subject is put into atomic energy, and that the results of the research are developed so that potential users can take the best advantage of them. It is important to realize that the effort required to develop a reactor system from the original idea into a commercial proposition takes approximately 1,000 man-years. Effort of this magnitude can only be made available on a national basis, so ensuring that there is adequate fundamental research over the whole atomic field.

The second function—perhaps of more immediate commercial interest—is that associated with the acquisition of uranium ores from the various mining areas throughout the world, and in converting this ore into fuel elements which can be used in the reactors designed and constructed by British companies.

The third function of the Authority concerns the manufacture and sale of isotopes through its Isotopes Division at Harwell and its Radiochemical Centre at Amersham. In the last 12 months, sales of isotopes have approached £¾ million, of which approximately 60% has been exported to the majority of overseas countries.

Fuel

Whilst British industry is now fully equipped to deal with the design and construction of the reactor, the provision of fuel is of equal importance. It is impossible to consider the economics of nuclear power without a guaranteed supply of fuel being available to an intending reactor operator at a price which is economic in relation to the level of performance.

The Authority has for many years been intimately concerned with the exploitation of the various uranium deposits throughout the world and has long-term purchasing arrangements with the various mining areas which will ensure a supply of uranium ore adequate to meet the anticipated programme for both home construction and export.

Apart from the certainty of adequate sources of uranium ore, the main requirements for the production of efficient fuel necessitate:—

(1) Extensive research and development effort over the whole field from ore to finished fuel element.

(2) Considerable manufacturing technology and experience.

(3) Experience gained under actual operational conditions on production quantities of fuel.

The Authority has for many years combined all these essentials with the benefits resulting from a closely co-ordinated team covering all aspects of the work, thus avoiding the inherent shortcomings which exist when responsibility in such an integrated technology is deployed over too wide a field.

It must be realized that Calder Hall, the first reactor of which has now been operating successfully for over two years, was the first full-scale nuclear plant anywhere in the world to provide electricity into a national distribution system. Operational experience gained in this way has proved invaluable, but even so it is only one facet of the Authority's fuel element experience. Special materials testing reactors have been built and are now providing facilities for investigating the performance of the materials used in the manufacture of fuel elements under accelerated irradiation conditions. This, combined with " out-of-pile " research work, emphasizes the unequalled position of the Authority as a supplier of natural uranium fuel elements for use in Calder type reactors.

A further advantage accrues to the purchaser of fuel from the Authority in that all aspects of the fuel transactions are covered in the one negotiation. The Authority is quite prepared to enter into long-term contracts (even up to 20 years should the purchaser so require) to provide a complete fuel service. This service can cover not only the supply of new fuel and the repurchase of irradiated fuel but also the provision of the special containers and flasks required for transporting the irradiated fuel. In this, as in every other sphere, the Authority also provides full information on appropriate health and safety standards.

Graphite

In order to assure the success of the Calder type reactor both in the U.K. and overseas markets, the Authority has taken steps to guarantee that nuclear graphite of the appropriate specification will be available within the U.K.

A considerable effort was required in achieving the correct nuclear purity and mechanical characteristics of the graphite. Working closely with the graphite manufacturers in this country, the Authority has been able to ensure that this essential raw material will be available for all gas cooled reactors built either in this country or overseas.

Overseas Markets

The Calder type of gas cooled graphite moderated reactor has greatest potential as a large land-based power station unit—the largest reactor now under construction being 250 MW(E). This means that its main application overseas will be in the more highly industrialized countries having substantial electricity requirements and adequate transmission systems. These same countries will have considerable indigenous engineering and metallurgical resources, and will naturally wish in due course to be as self-sufficient as possible in meeting their own internal nuclear needs.

This fact has been recognized both by the British manufacturers and by the Authority, and already the British companies are negotiating long-term licensing agreements with overseas organizations who will be able to build the major portion of the reactor plant under licence.

As regards fuel manufacture, one of the most important advantages of the Calder type reactor is that it uses natural uranium without the necessity for the vast capital investment and operating expense required for a diffusion plant, so that any country with a reasonably large nuclear power programme can become self-supporting both as regards fuel element fabrication, and even—in due course—reprocessing of irradiated fuel.

As production plants for these purposes require to have the support of a considerable research and development organization, they are unlikely to be economic until annual throughputs of approximately 1,000 tons of natural uranium can be achieved—this corresponding very approximately to an installed generating capacity of the order of 3,000 MW(E), operating at 80% load factor.

However, in parallel with the British reactor firms, the U.K.A.E.A. is quite prepared at a suitable time in the development of the atomic energy programme in an overseas country to assist in setting up fuel fabrication and reprocessing plants under the terms of commercial licensing arrangements.

Conclusion

In one way it is perhaps fortunate that our own energy shortage in this country directed the main impetus of atomic development towards the production of electricity. The U.K. nuclear civil power station programme is the largest of any country in the world.

The Authority is continually investigating other types of reactors and considerable progress has already been made in the design of an advanced gas-cooled reactor. Work on other systems, including the experimental fast reactor at Dounreay is continuing, but the present type of Calder reactor will remain the backbone of our programme for many years to come.

Throughout the whole nuclear field the Authority works in close association with British industry and any overseas purchaser has the assurance that in buying from this country he has available to him the combined atomic energy resources of the United Kingdom.

Les Exportations et l'Autorité de l'Energie Atomique du Royaume-Uni (U.K.A.E.A.)

Le rôle de l'Autorité de l'Energie Atomique du Royaume-Uni dans le cadre des programmes d'énergie et d'exportations commerciales nucléaires du Royaume-Uni fait l'objet d'une discussion. L'industrie prépare des projets et en entreprend la construction mais l'Autorité de l'Energie Atomique (la A.E.A.) s'occupe de la fabrication et du " re-traitement " des éléments de combustible. Tous les aspects de la manutention des combustibles font l'objet d'un seul accord avec l'Autorité qui est disposée à conclure des accords à long terme. Elle est aussi disposée à aider conjointement avec des firmes britanniques à l'établissement dans les pays d'outre-mer d'installations de fabrication et de " re-traitement." L'Autorité joue aussi un rôle capital dans la fourniture du graphite et dans l'exportation des isotopes.

Export und die U.K.A.E.A.

Es wird die Rolle der U.K.A.E.A. (Britische Atomkraft Zentralstelle) in Bezug auf das britische Kraftwerk Programm und die kommerzielle Atomkraft-Verwertung durch Export besprochen. Die Industrie macht die Entwürfe und unternimmt den Bau, während die Herstellung der Brennstoff-Elemente und deren Regenerierung die Aufgabe der A.E.A. ist. Alles, was die Brennstoffe und deren Handhabung betrifft, ist in einem einzigen Vertragsschema mit der Zentralstelle, der „ Authority," untergebracht, und die „Authority" ist bereit, Verträge auf lange Dauer abzuschliessen. Sie ist ferner bereit, zusammen mit britischen Firmen dabei zu helfen, in Uebersee-Ländern Fabrikations- und Regenerierungs-Werke aufzubauen. Die „Authority" spielt ebenfalls eine grössere Rolle in der Lieferung von Graphit und im Export von Isotopen.

Las Exportaciones y la U.K.A.E.A.

El papel de la U.K.A.E.A. en relación a los programas de energía y de exportaciones nucleares comerciales del Reino Unido es objeto de una discusión. La industria prepara, diseña y emprenda la construcción, pero de la fabricación de elementos de combustible y su " re-tratamiento " se ocupa la A.E.A. (Autoridad de Energía Atómica). Todos los aspectos del manejo de combustibles son objeto de un solo acuerdo con la Autoridad, que está dispuesta a concluir acuerdos a término largo. También está dispuesta a ayudar conjuntamente con firmas británicas en el establecimiento en los países de Ultramar de instalaciones de fabricación y " re-tratamiento." La Autoridad también desempeña un papel principal en el abastecimiento de grafito y en la exportación de isotopos.

Nuclear Engineering's Survey of the Manufacturing Field—1

Nuclear Power Plant for Overseas

By SIR CLAUDE GIBB,
K.B.E., D.Sc., F.R.S.
(Chairman, Nuclear Power Plant Co., Ltd.)

ALTHOUGH the design and construction of nuclear power plants for both home and overseas operation involve the same basic philosophies and most of the basic design team, the procedure and organizations are materially different.

The basic design team can only achieve maximum effectiveness if each component designer can discuss quickly with his colleagues, changes or fresh thoughts and their effects on other components in both technical and cost aspects. A new thought of the reactor physicist may affect fuel element design, reactor pressure vessel, heat exchangers, gas circulators, turbo-generators and even transformer output. Equally widespread in their effect could be changes in fuel element can configuration or in can material metallurgy.

Thus the closest contact between research worker and designer is essential for speed and effectiveness and as important as the hour to hour contact between physicist, metallurgist, aerodynamicist, thermodynamicist and engineers, civil, mechanical and electrical.

During World War II, the writer experienced the delays, frustrations, misunderstandings and general untidiness and inefficiency arising from geographical separation and lack of single direction of research, design and manufacture of munitions. He also participated in the almost unbelievable change of spirit, morale and effectiveness which resulted from a single control and amalgamation of research and design allied with manufacture.

It was this war experience, confirmed by following the same policy in industry subsequently, that led to the formation of the Nuclear Power Plant Company which comprises eight separate firms, each of them specialists in one or more fields of engineering yet together able to cover every aspect and component of a complete nuclear power station.

Parsons, with their 70 years' experience in the design and manufacture of steam and gas turbines, generators, blowers, compressors, transformers and optical work; with their long tradition of research and pioneering; their close contact with Harwell beginning in 1946 with the design and construction of the big cyclotron with which the first British isotope separation was made—and their association with the feasibility study from which Calder Hall was evolved, naturally led them initially to become responsible for the reactor physics, fuel element design including can material and configuration, gas circulators and ducting, turbo-generators, steam and water piping, dump and main condensers, general metallurgy, reactor instrumentation and collaboration in the overall design.

With the consolidation of the N.P.P.C. design headquarters at Knutsford in Cheshire, reactor physics and the basic requirements for fuel elements and reactor instrumentation are centred in that organization, but the basic research in metallurgy, physics, chemistry, reactor instrumentation and fuel element developments are still centred at Parsons. A new nuclear research centre devoted to this work is in course of construction at Parsons Heaton Works, and will be in operation by the end of this year.

Reyrolle, as the largest switchgear manufacturers in Britain and probably in the world, accepted the problems of control rod operation, all switchgear and control apparatus, the machining of graphite and some of the instrumentation.

Head Wrightson contributed their vast experience in chemical engineering, in heat exchangers, and in the design and manufacture of steel works plant and, with **Clarke Chapman** who are world famous boiler makers, undertook the design and manufacture of the heat exchangers. Head Wrightson also are responsible for the geometry of the graphite moderator design and for its laying within the reactors.

Clarke Chapman, through their subsidiaries and associated companies, provide the experience and manufacturing capacity for all lifting equipment including the Goliath crane capable of lifting 200 tons over the top of reactor biological shields and handling the reactor sections and heat exchangers as well as lighter equipment.

McAlpines almost certainly have carried out more of the civil engineering work associated with orthodox power stations than any other single firm and they have great experience in other civil engineering fields. They are responsible for civil engineering design and, in Britain, for civil construction. Their architects and consultants guide the aesthetics and appearance of the completed nuclear power station.

Whessoe, who designed and constructed the reactor pressure vessels for Calder Hall and Chapelcross, provide design and manufacturing experience and capacity for reactor pressure vessels for the Nuclear Power Plant Company. Whessoe have outstanding experience in the site fabrication of large complex pressure vessels, and since most of reactor pressure vessel welding must be carried out on site, this is invaluable.

Strachan and Henshaw have a long history of achievement in material handling and in the design of remote controlled mechanisms. They carry out the design and manufacture of the on-load charge/discharge gear.

Alex. Findlay have designed, supplied and erected the great majority of the structural steel for Capenhurst, Calder Hall and other establishments of the Atomic Energy Authority, and that and their vast power station experience makes them ideally suitable as the structural steel designers, fabricators and erectors for nuclear power stations in Britain or any overseas station in a country lacking

experience in steel structures of the magnitude and complexity involved.

But the mere bringing together of eight specialist firms into one company and with expert staff under one roof and one leader is not sufficient. Their work, particularly in construction, must be inspected and co-ordinated. Hence the experience of **Parolle** in the design and construction of orthodox and special purpose power plants is utilized, and many of their staff seconded to form the co-ordinating, inspection and progressing division of the N.P.P.C.

The foregoing outlines briefly the fields of each of the constituent companies and each of them supply both designs and manufacturing and construction capacity for nuclear power stations in Britain.

But for overseas nuclear stations the position is very different. In Italy for example, where their civil engineers deservedly are world famous, it is obvious that we could not expect to have McAlpines carry out the civil engineering work in the way they would in Britain. On the other hand, the civil engineering design is determined by reactor design and by the other major components and it is so interwoven and so much a part of basic design that inevitably it must be carried out step by step with the overall design. Thus McAlpines, in countries with adequate experience in civil engineering, would still be responsible for basic civil engineering design, and, as they have gained so much experience in the construction of the Bradwell station, that experience would be placed at the service of the selected civil engineering contractor in the country concerned.

The reactor design, in the most minute details, must always be carried out by the basic design team in conjunction with the specialist staff supplied by the appropriate member firm or firms concerned. Thus, arising from the main parameters determined by basic reactor physics calculations, fuel element type and behaviour, reactor control and operation requirements and by successive optimization studies, the gas circulators and ductwork designs provided by Parsons' staff must be dovetailed with reactor pressure vessel design by Whessoe; with the internal measuring equipment for temperature and for graphite movement; for the internal supporting structure for graphite and fuel and the graphite restraining mechanism, and all this with the control rods and their operating mechanism and with the charge/discharge gear.

The civil engineering design for reactor foundations and the many equipment and subcontrol rooms dovetailed around the biological shield are an integral part of the reactor and must be designed stage by stage as the reactor design proceeds. Thus Parsons, Reyrolle, Head Wrightson, McAlpines, Whessoe and Strachan and Henshaw all are concerned intimately with the reactor design.

Just as the problems of heat transfer from fuel rod through the can to gas are vital to the efficiency of the reactor, so equally vital is the heat transfer from gas to water and finally to steam, for the overall efficiency of the whole nuclear station. A highly industrialized country might well be able to manufacture the heat exchanger shells with advice, assistance and supervision from Head Wrightson and Clarke Chapman, but it is likely that the special extended surface tubes will be supplied from Britain because it is upon their heat transfer per foot length of tube that shell size and overall costs depend.

The spherical reactor pressure vessel demands highly specialized equipment for the pressing of the large number of plates which need great experience for their satisfactory welding into the complete shell. The possibility of brittle fracture occurring during fabrication or before final stress relieving is a factor always in the mind of designers and fabricators. The steel used must have a low transition temperature and excellent notched ductility yet have creep properties suitable for the temperature and stress under which the upper half of the vessel operates. Welding sequences must be such that stresses are kept to a minimum and it is here that long experience (possibly some of it bitter) can save much time, money, worry and risk. The high cost of the special equipment for pressing and preparing the plates is such that it is unlikely to be justifiable or economic to provide unless a reasonable use factor is available for the plant either for a continuous flow of reactor construction or some similar work. The special quality steel plate, the expensive equipment and the experience in welding necessary for successful fabrication make it sensible and highly desirable that the reactor pressure vessel should be supplied by the specialist firm possessing the essential equipment and experience, even though trained welders of the country in which the nuclear station is being built are used for site welding.

The graphite used as the moderator must be of the highest possible purity to have the lowest neutron capture and of the highest density to keep the reactor dimensions to a minimum. A moderator having a relatively high neutron capture (such as light water) almost certainly will require the use of enriched uranium whereas one with a low capture such as heavy water will permit the use of natural uranium. Graphite has a higher neutron capture than heavy water but lower than light water if of reasonable purity. Graphite, if of exceptional purity, that is a cross section capture less than 3.9 millibarns and a density higher than 1.7, can be produced if petroleum coke and pitch carefully selected for their purity are used as raw materials and exceptional precautions to avoid contamination are taken. The new nuclear graphite factory established by Parsons, Reyrolle, McAlpines and Clarke Chapman in conjunction with the Great Lakes Carbon Corporation of U.S.A. is now in operation at Newburn Haugh near Newcastle upon Tyne. The new company formed to carry out this project is called the **Anglo Great Lakes Corporation Ltd.,** and went into production in barely 17 months from the cutting of the first sod at a cost approaching six million pounds. A large number of hand-picked engineers and scientists went to America for the essential training and experience while three very experienced Great Lakes Carbon Corporation technicians are supervising production and technical control during the first several years of operation.

The close alliance between the Nuclear Power Plant Co., and Anglo Great Lakes Corporation, both working closely with the United Kingdom Atomic Energy Authority, ensures a continuous programme of graphite research and development leading to still further improvements in those properties of graphite necessary for the advanced reactors already envisaged by the nuclear physicists and engineers.

Nuclear power stations producing electricity for public supply systems should have as a basic philosophy of design the provision of firm power. This necessitates that fuel elements must be capable of being changed whilst the power station remains on full load. Uranium must be regarded as merely another fuel complementary to coal or oil. Incipient leakage in any fuel element must be capable of early detection and replacement. Equipment for doing this in a gas-cooled graphite moderated reactor is by no means simple but an elegant solution to the problem has been produced and the four nuclear stations currently building in Britain all incorporate such equipment.

The Latina Nuclear Station, south of Rome, to be constructed jointly by Agip Nucleare and the Nuclear Power Plant Co., for SIMEA will have an output of 200 MW net

from one reactor, six heat exchangers and three main turbo-generators with two auxiliary turbo-generators, one supplying the variable speed motor driven circulators with the other as standby. As at Calder Hall and the four British stations, steam to the main turbines will be at two pressures and special governing problems are involved.

It is not always realized that the highest possible efficiency is essential from the turbo-generators both main and auxiliary. By far the major part of the total station capital cost is incurred in the reactor and its auxiliary equipment and in the heat exchangers. The turbo-generators represent only between 10 and 12 per cent. of the station cost.

Taking round figures of say £100 as the cost per kW of output for the complete station of which £10 is the cost per kW of the turbo-generators, it is seen that the cost of housing the turbo-generators and supplying them with steam is roughly £90 per kW. Thus every additional kW which can be produced from a given quantity of steam is worth, not the full £90/kW, but a figure approaching that. The difference in capital cost between a high efficiency and a low efficiency turbo-generator is small in relation to the overall station cost. Hence the turbo-generators must always be designed for maximum efficiency consistent with reliability. But reliability must always be predominant since any unforeseen or unplanned outage of a high capital cost station means a serious financial loss.

It is this emphasis upon reliability which needs so much stressing when considering the selection of manufacturers in countries overseas who may well believe themselves quite capable of fabricating components to the basic designs of a British company.

Valuable experience being gained with the design and construction of the British nuclear station now is being applied in Italy to a joint project with some components supplied from Britain and others manufactured in Italy. The Agip Nucleare scientists and engineers already have received the respect and friendship of their British counterparts and the pattern of co-operation between the two countries will serve as the basis of contracts in other countries.

(*Translations on page* 366)

N.E. Manufacturing Survey—2

The Overseas Demand for Nuclear Plant

By **E. M. PRICE**, M.A., M.I.Mech.E., M.I.E.E.,
General Manager, Atomic Power Division, The English Electric Co., Ltd.
(Member of the English Electric, Babcock and Wilcox, Taylor Woodrow Atomic Power Group)

AT the Geneva Conference in 1955 many papers were presented estimating energy resources and future power requirements, both globally and in respect of individual countries. It was recognized that atomic energy had an important part to play in meeting the deficiency between requirements and resources of energy which is becoming increasingly evident in many parts of the world. In the interval between August, 1955, and the current Geneva Conference, what was then almost exclusively a matter of scientific interest has now developed into a matter of business. Large organizations have developed, capable of selling nuclear power stations, and some countries are showing interest in buying them.

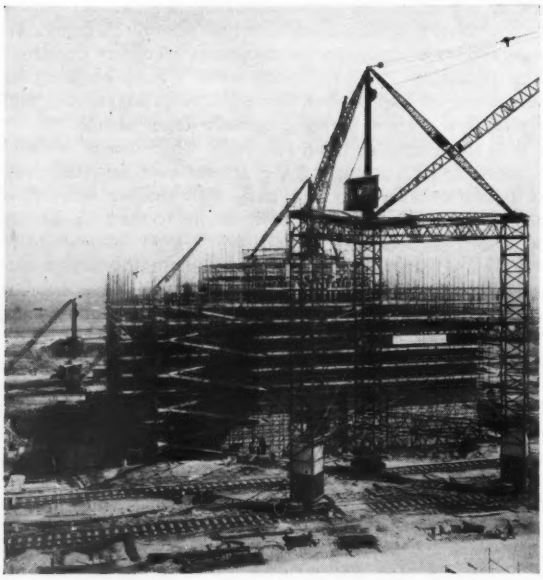
The pattern of inquiries from different countries is now becoming sufficiently established to indicate the place that atomic energy can fill at this stage of development in the overall demand for electrical energy. The first countries to which atomic power makes a special appeal are those whose other natural power resources are limited, for example, where all economic hydro projects may have been fully developed or coal or oil for thermal power may be too expensive, or supplies too unreliable. Nuclear power stations are admittedly higher in capital cost, but despite this higher cost it has always been recognized that the relatively low fuel and operating costs go a long way to offset this disadvantage and bring the cost per unit of electricity generated into the same range as that from thermal stations.

In terms of units of electricity, however, cost differences of fractions of a penny are important and millions of pounds of money are being spent by groups such as the **English Electric—Babcock and Wilcox—Taylor Woodrow Group** interested in the commercial development of atomic power to improve designs, and to reduce capital and running costs, all with the aim of lowering the cost per unit of electricity to a level where atomic power is on a comparable economic basis to that for electricity generated from coal, oil, or hydro power.

The station which the Group is constructing at Hinkley Point is expected to generate electricity at less than the present average generating cost in the United Kingdom. This, although an achievement in itself, is merely a milestone on the way, for as Sir Christopher Hinton so clearly forecast the cost of atomic power must surely outstrip other forms of power generation, well within the professional life of most of those now engaged in the design and development of these stations.

Despite the technical improvements which are evident in Hinkley Point, and despite the substantial development efforts being applied, the most important factors influencing the economy of nuclear power stations are the output of plant being constructed and the load factor at which it will operate. Reduce the output of the station projected and the cost per kW of the installation rises sharply; increase the output required and the cost per kW dips. These features have clearly appealed most to those countries whose electricity requirements call for large blocks of power, industrialized countries who can absorb all the power from the station most hours of the day and most days in the year.

The design of any nuclear power station is, of course, an extremely complicated process, but the development of acceptable proposals for an overseas country brings further problems in its train, which call for considerable engineering judgment and a clearsighted appreciation of the



The reactor structure at Hinkley Point.

economic and commercial factors involved. These industrialized countries have their own tradition as manufacturers and suppliers of conventional power station equipment and are therefore anxious to extend their interests into the nuclear field rather than see their business curtailed. The construction of a nuclear station involves a certain amount of work which must be done on the site, such as the construction of civil engineering and building works and the erection of pressure vessels, steam-raising units and ducting, the laying of graphite and erection of other reactor components as well as the erection of all the conventional generating equipment. All such operations might represent between one quarter and one-third of the total cost of a station. In addition, however, there is a considerable amount of additional work that can be undertaken locally. The precise amount must, of course, vary from case to case, but the manufacturing facilities of most of the industrialized countries have developed to the stage where the supply and preparation of the heavy steel plates for vessel fabrication, supply of all conventional generating equipment, and also of a certain amount of hardware in the reactor itself is quite feasible. This can result in as much as perhaps two-thirds of the total cost being carried out locally.

At this point it is clear that a balance must be struck between the understandable desire to supply as much as possible of the equipment from this country or to embody the maximum amount of locally manufactured equipment, so increasing the business of countries who have, in more conventional fields, been our competitors. For many years now, however, the trend towards more and more local manufacture overseas has been evident in many fields of business, and, in the case of our own particular Group, has been acknowledged by the establishment of manufacturing facilities in many countries and by the formation of licensing associations with many overseas companies. Much of our activity in industrialized countries overseas must therefore be more in the role of designers, consultants and suppliers of special plant, rather than as providers of conventional equipment. For example, the low steam conditions which are a feature of the British type of reactor, call for turbine exhausts of unusually large size in order to minimize the leaving losses in the turbine. The large amount of development already carried out to solve these problems arising in the very large turbines for conventional thermal stations now being designed and constructed in this country, enables Groups such as our own to share this experience with other countries who have not so far had to undertake such developments.

Decisions as to the location of manufacture of the various items in the station must, of course, be made at a fairly early stage in the development of a project, for these

L'English Electric/Babcock & Wilcox/Taylor Woodrow Group actuellement occupé à la construction de la plus grande centrale d'énergie nucléaire du monde à Hinkley Point est en train de traiter activement avec des pays étrangers de l'achat de centrales d'énergie nucléaires. L'article passe en revue le marché actuel des grands réacteurs et la balance à faire entre la fabrication dans le pays acheteur et au Royaume-Uni.

Die Gruppe, die die English Electric, Babcock & Wilcox und Taylor Woodrow umfasst und zur Zeit mit dem Bau des Atom-Kraftwerkes in Hinkley Point, dem grössten der Welt, beschäftigt ist, ist in fortgeschrittenen Verhandlungen mit dem Ausland über den Verkauf von Atom-Kraftwerken. Der Aufsatz behandelt die Frage des derzeitigen Marktes für grosse Reaktoren und den Ausgleich, der gefunden werden muss, zwischen der Herstellung im Lande des Käufers und in Gross-Britannien.

El Grupo English Electric/Babcock & Wilcox/Taylor Woodrow actualmente ocupado en la construcción de la central de fuerza nuclear más grande del mundo en Hinkley Point, está activamente negociando con países extranjeros para la compra de centrales de fuerza nucleares. El artículo discute el mercado actual para reactores grandes y el equilibrio que debe haber entre fabricación en el país comprador y en el Reino Unido.

A.E.I.—JOHN THOMPSON NUCLEAR ENERGY CO., LTD. (page 373)

L'A.E.I.—John Thompson, actuellement occupée à la construction de la centrale de Berkeley fournit aussi des réacteurs d'études modérés à l'eau légère aux Laboratoires de Recherches de l'A.E.I., l'A.W.R.E. er l'Allemagne. En outre, cette compagnie a joué un rôle important dans les développements thermo-nucléaires du Royaume-Uni et dans l'appareil Sceptre III elle a obtenu des températures de l'ordre de 4M° dans un plasme stabilisé pendant plusieurs centaines de microsecondes. La compagnie est prête à offrir des dessins de centrales nucléaires considérablement plus petites que l'installation de 275 MW à Berkeley.

A.E.I.—John Thompson, die zur Zeit mit dem Bau des Berkeley Kraftwerkes beschäftigt sind, arbeiten gleichfalls an mit gewöhnlichem Wasser moderierten Forschungsreaktoren für die A.E.I. Forschungs-Laboratorien, für A.W.R.E. und für Deutschland. Die Gesellschaft hat eine prominente Rolle in der Entwicklung thermo-nuklearer Technik in Gross-Britannien gespielt und in der Apparatur von Sceptre III Temperaturen von der Grössenanordnung 4 M° erzielt, die im Plasma während mehrerer hundert Mikrosekunden stabilisiert blieben. Die Gesellschaft ist bereit Entwürfe für Atomwerke zu liefern, die beträchtlich kleiner sind als das 275 MW-Werk in Berkeley.

La A.E.I.—John Thompson está actualmente ocupada en la construcción de la central de fuerza de Berkeley, y además está suministrando reactores de investigación con moderación por agua ligera a los laboratorios de investigaciones A.E.I., A.W.R.E. y a Alemania. Además, esta Compañía ha desempeñado un papel importante en las evoluciones termonucleares del Reino Unido y en el aparato Sceptre III han alcanzado temperaturas del orden de 4M° en una plasma estabilizada durante varios centenares de microsegundos. La Compañía está dispuesta a ofrecer diseños de centrales nucleares considerablemente más pequeñas que la planta de 275 MW en Berkeley.

can affect the overall conception of the design. It is necessary to ensure a proper balance between various sections of the station in determining the main parameters of the system. For example, there may be a possibility of varying the extent of concrete work in relation to steel work. Clearly where in a particular country concrete work is cheap, it will pay to reduce the amount of steel work, at the expense of extending the concrete work, or again, there may be a choice between substantial manufacture of a component in a works with only a small amount of erection on site, as compared with substantially complete construction on site. Although transport considerations may also be important here, the cost of the two methods may be very different. It is not sufficient to assume that the best choice for this country would also apply overseas, for labour rates are not similar and the differential between skilled and unskilled labour rates in this country appears to be less than in many other countries. Fairly accurate cost information is therefore required for all types of plant and equipment and civil engineering works required in the station, so that the most economic design can be achieved, and such information must be obtained before the design commences. In relation to the detail design of equipment, there are, of course, different practices and standards in other countries and these too must be taken into account as far as it is possible, without prejudicing the cost or the safety and reliability of the station.

The conditions for which a station is to be designed introduce further variables in each project. For countries like Japan, of course, there is the very real problem of earthquakes, and to make the plant resistant to these is a technical problem calling for an intensive programme of theoretical and experimental work of a high order. On a smaller scale, although none the less fundamental, are the problems of foundation design for the reactors which result from the ground conditions of the selected site. These can, and do, vary from good rock substrata to marsh or sand, and their influence on the design of the station can have a noticeable effect on the overall economics of the scheme.

In achieving a design acceptable from both the economic standpoint and from the point of view of practicability of construction and operation in the particular country, it is evident that a very full exchange of information is required between specialists from both purchasing and supplying countries. We, in this country, can define the limits within which we can adapt the type of nuclear station we are selling, but the final solution cannot be determined in practical form without knowing the particular conditions in the countries concerned and what can or cannot be done there. This is but a new and perhaps more extensive example of the technical co-operation between Great Britain and other countries of the world which has been a feature of our overseas relations since the industrial revolution and before.

The first International Conference at Geneva was marked by the free disclosure of scientific discoveries to the world at large. The intervening period has seen a continuation of this co-operation in the commercial development of atomic energy. The actual task of executing work of this kind which is now imminent will necessitate even closer co-operation and partnership between the various industrial organizations in the countries concerned not only in manufacture and construction, but also in the training of technicians and the ultimate commissioning and successful operation of these stations.

N.E. Manufacturing Survey—3

Commercial Nuclear Power Stations and Research Reactors

By H. WEST, M.Sc., M.I.Mech.E., M.I.E.E.
(*Managing Director, A.E.I.—John Thompson Nuclear Energy Co., Ltd.*)

AT the second Symposium on the Peaceful Uses of Atomic Energy held in Geneva a detailed account is given by Ghalib and Southwood of the design of the Berkeley 276 MW nuclear power station.[1] Also presented in papers by Allibone and others[2] is a description of the design of the Merlin research reactors, three of which are at present under construction.

Berkeley and Merlin are the first fruits of the **A.E.I.—John Thompson Nuclear Energy Co., Ltd.**, an organization formed less than four years ago and which numbered in September, 1954, no more than half a dozen men. It now comprises scientists, engineers and draughtsmen, who with their attendant services number over six hundred people.

High Output Power Reactors

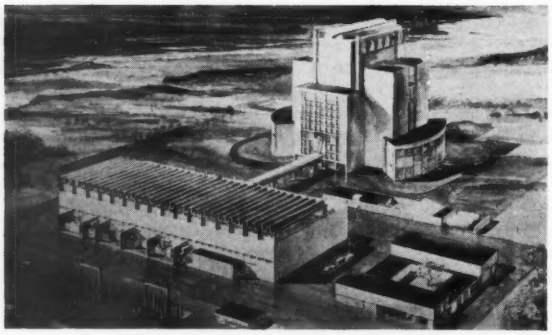
It is already two years since our design for the Berkeley nuclear power station was tendered in open competition with three other British consortia.

In September, 1956, we were able to demonstrate that the economic net electrical output per reactor at that time lay in the region 130-150 MW. Consequently the two Berkeley reactors were each designed for an output of 138 MW.

Today we are actively engaged in the detailed design of reactor units each capable of economic net electrical output of more than 250 MW. These designs are aimed primarily at the forthcoming competition for the next round of Central Electricity Generating Board nuclear stations.

The British electricity network for which these reactors are specifically designed is of course unusually highly integrated, with a present base load of over 3,000 MW and an operational stability capable of sustaining the loss of single unit generators as large as the 550 MW which will be commissioned in 1963. Overseas there are comparatively few power systems capable of absorbing such large units and, of these, fewer still in which the cost of power generated in nuclear stations can compete economically. Nevertheless these reactors are available for export now.

1. "The Berkeley Power Station" by S. A. Ghalib and J. R. M. Southwood.
2. "The Merlin Research Reactor" by T. E. Allibone, D. R. Chick and K. Firth.

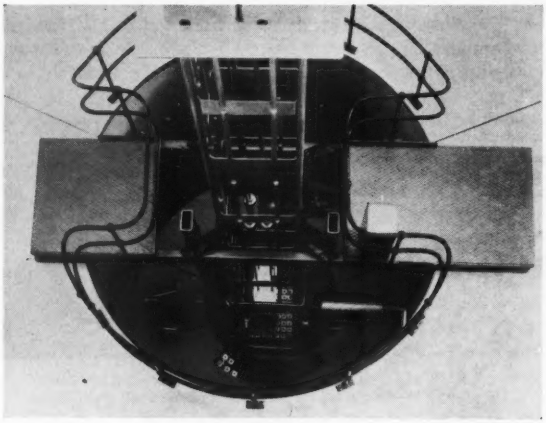


Typical 150 MW single reactor power station.

Medium Output Power Reactors

By utilizing the same basic design and many of the components developed for the high output power reactor, we are able to offer reactor units in the range 100-200 MW which satisfy the requirements of a larger overseas market. Typical of these designs are those currently offered to Dutch, German, Italian and Japanese power system operators.

A typical A.E.I.—J.T. design is the single reactor station of 150 MW net electrical output shown above with four gas circuits and reinforced cylindrical pressure vessel combining greatly enhanced gas system pressure with the practical constructional and operational advantages of the cylindrical form.



Model of MERLIN research reactor.

Low Output Power Reactors

Of interest to industrial operators at home and overseas are designs for 50-100 MW (equivalent total net electrical output) reactors delivering both power and process steam. These have been considered in both the natural uranium and enriched fuel versions. The unit sent out cost of such reactors can be attractive in areas remote from conventional fuel sources.

The main deterrent to users has proved to be capital shortage in the locations where these reactors could otherwise be very suitable economically from a unit sent out cost point of view.

MERLIN Research Reactors

For the serious study of nuclear physics and behaviour of materials under neutron bombardment a high flux research reactor of relatively low cost is an essential tool.

Merlin having the relatively low maximum thermal output of 5 MW does not have to be contained and apart from the highly enriched fuel employs no significant quantities of expensive materials in its construction.

It is light water moderated and cooled and by a simple vertical travel facility the core can be located in two experimental positions.

Thus within a compact biological shield a large number of experimental holes are accommodated. By omitting a central fuel element and raising the critical mass by a fraction of a kg an experimental space is provided offering a neutron flux of 5×10^{13} n/cm², sec thermal and 2×10^{14} epithermal.

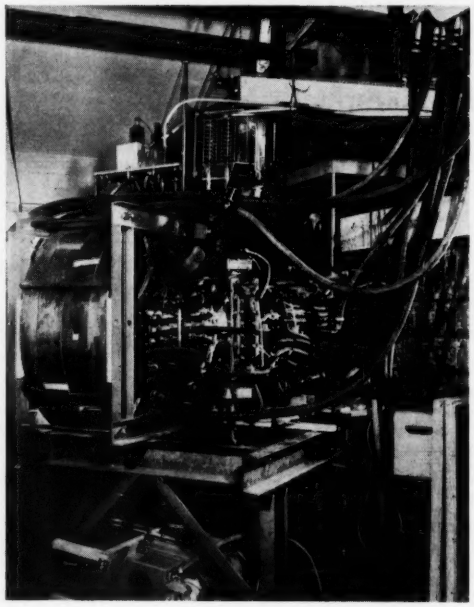
Provision is made for adding a $2\frac{1}{2}$-in. thick beryllia reflector to the core which will increase these maximum fluxes to 7×10^{13} thermal and 3×10^{14} epithermal.

By careful design and acceptance of a reduced experimental load Merlin makes it possible for a private research centre to carry out high neutron flux experiments at a capital cost of about a fifth of that of the high flux research reactors used by the national laboratories. Because of the moderate power the fuel running costs are also lower in proportion.

Three of these reactors are at present under construction; at Julich, North Rhine Westphalia, at the Atomic Weapon Research Establishment, Aldermaston, Berkshire, and at A.E.I. Ltd.'s private long-term research laboratory at Aldermaston Court.

Thermo-nuclear Research

The A.E.I.-John Thompson Nuclear Energy Co., Ltd., is two-thirds owned by Associated Electrical Industries Ltd.,



SCEPTRE III, the small thermo-nuclear device at Aldermaston Court.

at whose Group Laboratories at Aldermaston Court the "Sceptre" thermo-nuclear research apparatus has been installed.

"Sceptre" is the only private venture thermo-nuclear device in Britain and is closely related to the Atomic Energy Authority's "Zeta" at Harwell in the design of which the A.E.I. Group played a leading part through its subsidiary, the **Metropolitan-Vickers Electrical Co., Ltd.**

(*Translations see p.* 372)

NUCLEAR GENERATION in the UNITED KINGDOM

The Programme and the Power Stations

ALTHOUGH the decision had been taken to pressurize the Calder Hall reactors and use the heat generated to produce electricity for feeding into the National Grid, at a relatively early stage in U.K. atomic energy developments, the nuclear power station programme was effectively launched in February, 1955, with the Government White Paper, which projected the construction of 2,000 MW installed capacity by 1965. This assumed that some twelve stations would be required, each comprising two reactors rated at something over 80 MW (E) and 200 MW (thermal). Calculations made at the time indicated that power costs would be in the region of 7 mill/kWh when a plutonium credit equivalent to 4 mill/kWh was allowed. Subsequent research into the value of plutonium as a nuclear fuel indicated, however, that this credit allowance could not be justified and a drastic reduction by a factor of five was considered a more realistic assessment. In the meantime, the four industrial consortia which had been set up to prepare designs of commercial stations, for submission to the generating authorities on a fixed price basis, had shown that a notable advance could be made on the Calder prototype, in particular, by increasing the unit size of the reactor to give greater pressure vessel utilization, increased flattening across the core and higher gas temperatures with a resultant decrease in capital cost per kilowatt installed. This lowering of cost would largely offset the reduced plutonium credit.

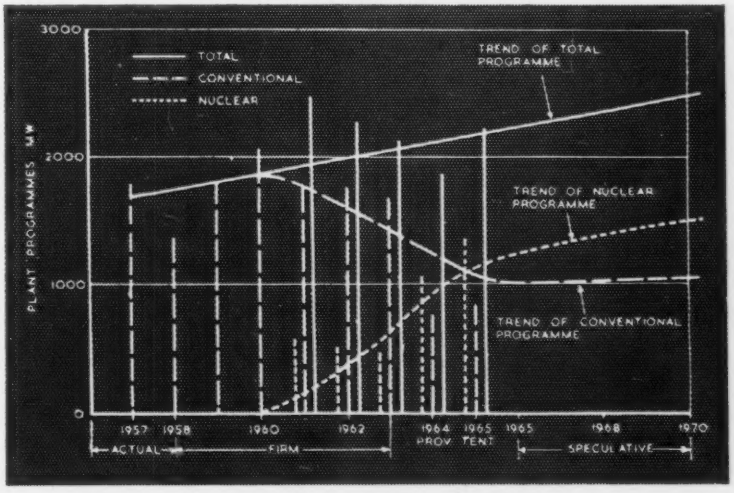


Fig. 1.—Annual programme for conventional and nuclear plant, showing possible trends.
(*Hinton, B.E.P.C., June*, 1958)

In March, 1957, therefore, it was felt that a substantial increase in the programme was desirable. The target was raised to a figure of 5,000 to 6,000 MW by 1965 and the possibility was mooted that fossil fuel fired stations would not be built after that date. Parallel to nuclear developments, however, a considerable capital outlay has been made on the mechanization of the coal mines, with the result that the small coal supply position in the U.K. has materially improved. In addition, the overall economic situation of the country forced the Government during 1957/58 to restrict capital investment, and in order to fall in line with this national policy the generating authorities (in particular the Central Electricity Authority—now the Central Electricity Generating Board) decided that the 1957 programme could no longer be met and put back the target of 1965 by twelve to eighteen months.

Fig. 1, taken from Sir Christopher Hinton's paper to the British Electric Power Convention held in June, indicates the probable new construction programme of the C.E.G.B. over the years 1958 to 1970 (on present evidence). Provision has been made for the construction of fossil fired stations at the rate of around 1,000 MW per year to continue into the 1970s on the assumption that a small coal surplus will continue. It should be noted that the figures for nuclear stations do not take account of the 300 MW which will be supplied to the grid from the Calder Hall and Chapelcross stations when these are finally fully operational in early 1960, nor of the 300 MW Hunterston station under construction for the South of Scotland Electricity Board and due to come into operation in 1961/62. In addition, a nuclear station is projected for Northern Ireland of 200 MW capacity to come into operation in 1963/64. The Northern Ireland plans imply a considerable confidence in nuclear generation as doubling of this capacity by 1969 is anticipated and nuclear generation will then represent 40% of the total installed capacity of the country, whilst 75% of the units sent out will be generated in fission stations.

At present the C.E.G.B. has three stations under construction, Berkeley 275 MW, Bradwell 300 MW and Hinkley Point 500 MW. These will come into commission

(*Continued on page* 378)

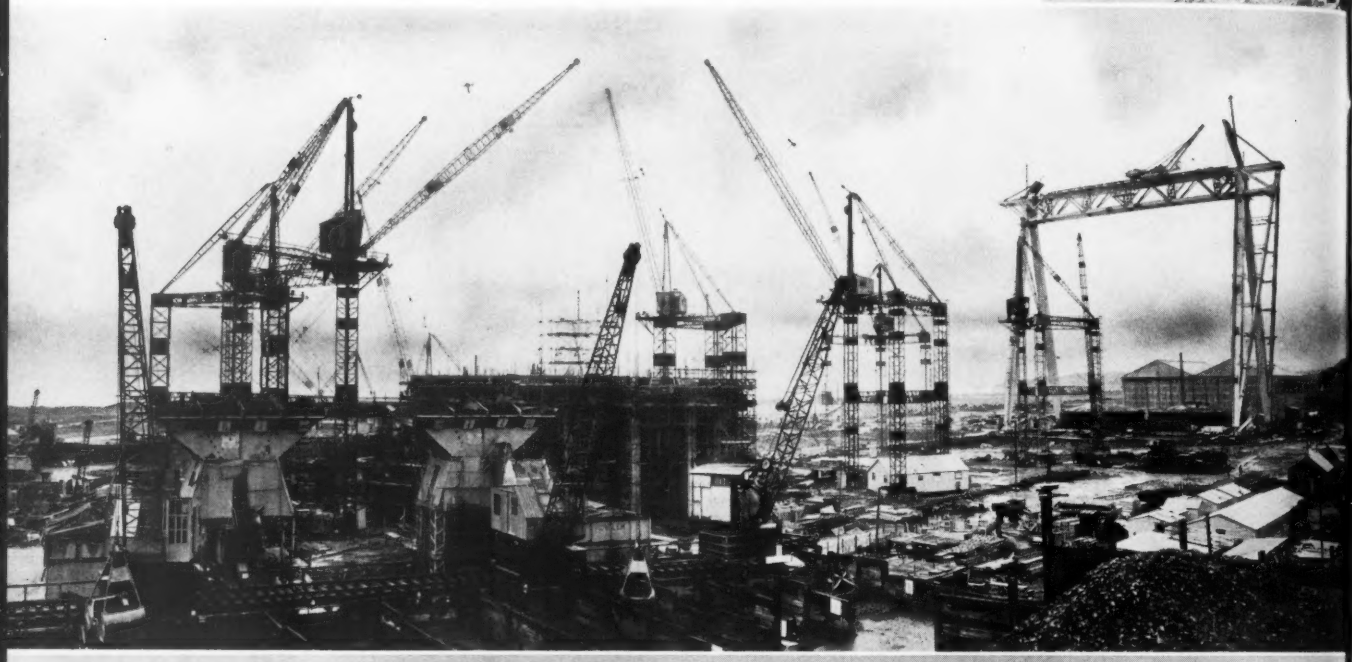
PROGRESS AT THE SITES

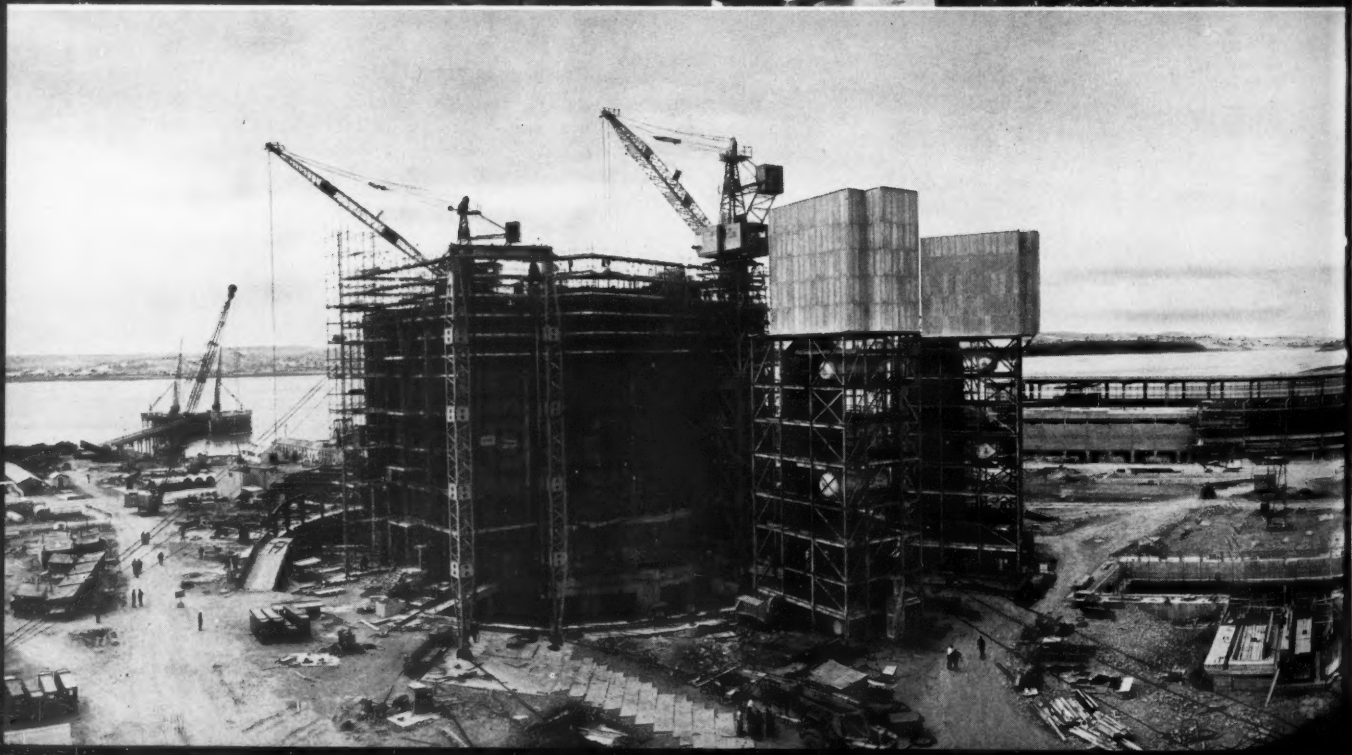
(Top) Hinkley Point (English Electric—Babcock and Wilcox—Taylor Woodrow).

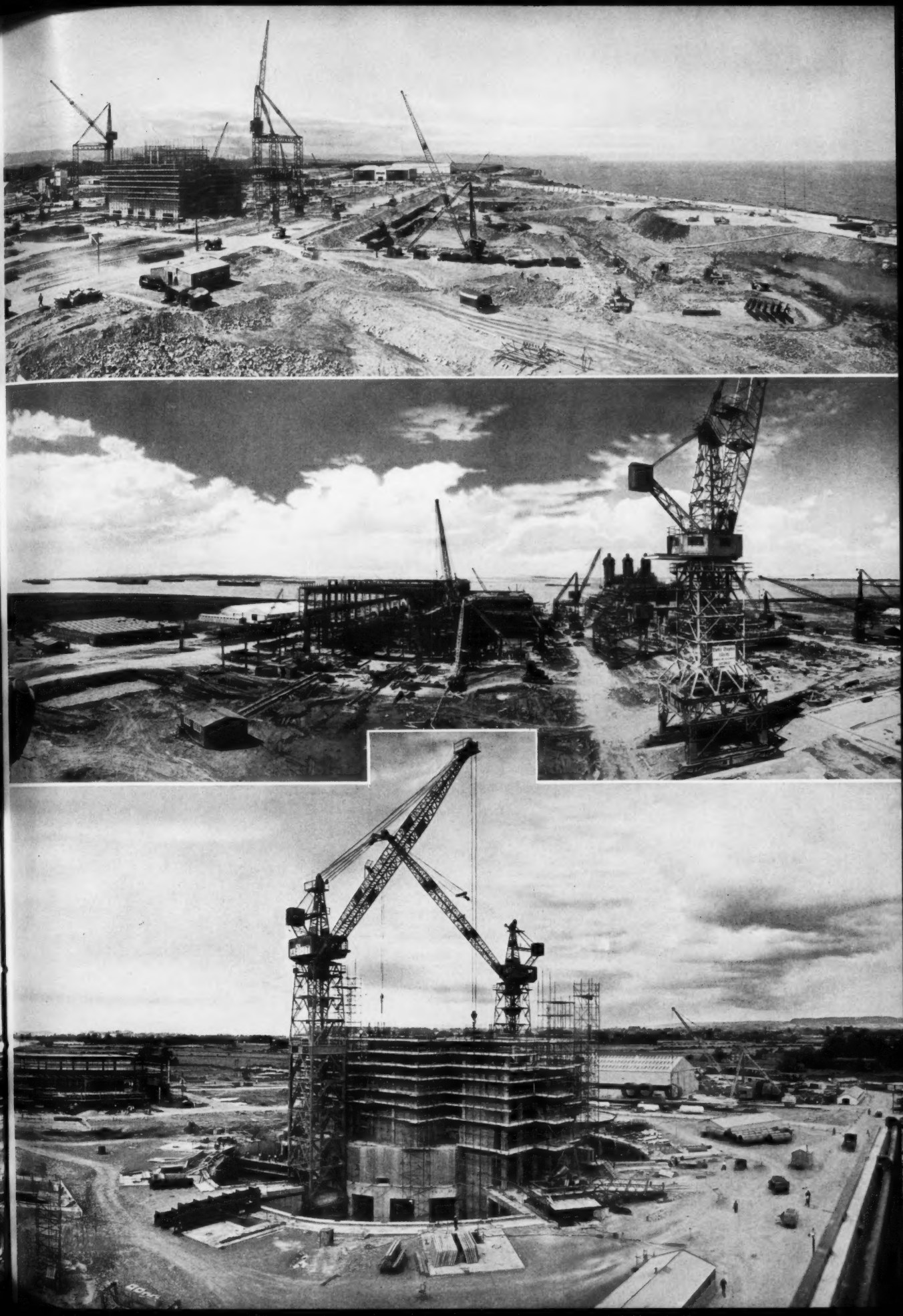
(Centre, left) Hunterston (G.E.C., Simon-Carves).

(Centre, right) Bradwell (Nuclear Power Plant Co., Ltd.).

(Bottom) Berkeley (A.E.I.—John Thompson).







over the two years 1960 and 1961. Potential sites are being investigated for subsequent development all over the U.K. and the co-operation of local authorities sought; these include locations in Kent (Dungeness), Suffolk, North Wales (Ederne) and South Wales. Approval was given in July by the Minister of Power for the erection of a 400/500 MW station at Trawsfynydd in North Wales and tenders for this station will be examined during the Spring of next year. Approval for other sites will follow in due course and contracts for the further stations will be placed over the following four years.

It must be emphasized that the C.E.G.B. programme for the period after 1966 is essentially speculative. Changing political and economic conditions could adversely affect the supply and cost of fossil fuels, while the burn-up in nuclear fuel elements has yet to be operationally established. There is, nevertheless, considerable confidence on this last point and a general expectancy that the capital cost of nuclear stations will steadily reduce. In addition to present developments which concern detailed engineering of both main reactor units and components, increase in the capacity volume ratio of the reactor and advances in control techniques, attention is being directed by both industry and the A.E.A. towards the development of an advanced type of gas-cooled reactor incorporating beryllium as a canning material and permitting steam conditions to be realized which are comparable with those of the most modern conventional power station. To this end a prototype reactor will be built by the Industrial Group of the Atomic Energy Authority in the near future on a site not yet published but believed to be adjacent to the present Calder Hall station.

THE STATIONS COMPARED

	Calder Hall "A"	Berkeley	Bradwell	Hinkley Point	Hunterston
Operator	U.K.A.E.A.	C.E.G.B.	C.E.G.B.	C.E.G.B.	S.S.E.B.
Designer	U.K.A.E.A.	A.E.I.—J.T.	N.P.P.C.	E.E.—B.W.—T.W.	G.E.C., S.-C.
Prime purpose	Plutonium prod.	Power	Power	Power	Power
No. of Reactors	2	2	2	2	2
Installed capacity	92 MW (4 sets)	340 MW (4 sets)	328 MW +61 MW aux.	561 MW +99 MW aux.	360 MW (6 sets)
Guaranteed output	~75 MW	275 MW	300 MW	500 MW	300 MW
Reactor output (H)*	200 MW	550 MW	530 MW	980 MW	535 MW
Critical No. 1	May '56	mid '60	mid '60	mid '61	Early '61
No. 2	Nov. '56	end '60	end '60	end '61	Early '62
Fuel	Nat. U rods	Nat. U rods	Nat. U rods	Nat. U rods	Nat. U rods
Charge*	120 tonnes	253 tonnes	237 tonnes	376 tonnes	249 tonnes
U rod dia.	1.15 in.	1.1 in.	1.155 in.	1.10 in.	1.15 in.
Rod length	40 in.	19.2 in.	36 in.	36 in.	24 in.
Support	Stacked	Graphite struts	Stacked	Stacked	Graphite sleeves
Cladding	Magnox C	Magnox A12	Magnox A12	Magnox A12	Magnox A12
Cladding thickness	0.072 in.	—	—	—	—
Fin dia.	2.125 in.	—	—	—	—
Max. can temp.	408°C	424.5°C	450°C	430°C	454°C
Core height	21 ft	24 ft	25 ft 8 in.	25 ft eff.	23 ft
Core dia.	31 ft	44 ft	40 ft 1 in.	49 ft eff.	44 ft 6 in.
No. fuel channels	1,696	3,275	2,575	4,500	3,288
No. elements/channel	6	13	8	8	10
Central channel rating	~100 kW	214 kW	336 kW	258 kW	201 kW
Lattice pitch	8 in. sq.	8 in.	8 in.	7.75 in.	8.25 in.
Initial excess reactivity	4%	4%	—	—	4.5%
Moderator	Graphite	Graphite	Graphite	Graphite	Graphite
Wt. of graphite	1,146 tonnes	2,134 tonnes	1,910 tonnes	2,032 tonnes	2,180 tonnes
Control rod material	Boron steel	4.25% boron steel	Boron steel	Boron steel	Boron steel
Number	~60	132	120	—	164
Dimensions	22 ft long	307 in. × 1.75 in. dia.	28 ft × 2.25 in. dia.	—	21 ft × 2 in. dia.
Drive	Synchronous motor	Synchronous motor	VF induction motor	VF induction motor	Synchronous motor
P.V. shape	Cylindrical	Cylindrical	Spherical	Spherical	Spherical
P.V. dimensions	70 ft × 37 ft i.d.	80 ft × 50 ft i.d.	66 ft 9 in. m.d.	67 ft o.d.	70 ft i.d.
P.V. plate	Low tem. Al-killed mild steel	Si-killed m.s.	Special m.s. plate	28/32 Si-killed boiler steel	Coltuf 28
Plate thickness	2 in.	3 in.	3 in.—1 in.	3 in.	2⅞ in.—3 in.
Max. temp.	<400°C	300°C	380°C	<344°C	
Operating pressure	100 p.s.i.g.	125 p.s.i.g.	132 p.s.i.g.	185 p.s.i.g.	150 p.s.i.g.
Coolant	CO_2	CO_2	CO_2	CO_2	CO_2
Inlet temp.	140°C	160°C†	180°C†	180°C†	204°C
Outlet temp.	336°C	345°C	390°C	375°C	391°C
Mass flow	1,964 lb/sec	6,350 lb/sec	5,262 lb/sec	10,300 lb/sec	5,900 lb/sec
Central channel M.F.	~1.2 lb/sec	2.3 lb/sec	2.53 lb/sec	2.8 lb/sec	2.25 lb/sec
Duct dia.	4 ft 6 in.	5 ft	5 ft	6 ft 6 in.	5 ft
Circulators	4, centrifugal	8, single stage axial	6, single stage axial	6, single stage axial	8, centrifugal
Drive	Ward-Leonard	Constant speed motor, hydraulic coupling	v.f. motors from v.s. aux. t.-a.	v.f. motors from v.s. aux. t.-a.	d.c. motors, grid controlled rectifiers
Blower power	5.44 MW	8×2.38 MW	6×2.53 MW	6×7,000 h.p.	8×1.76 MW
No. of boilers	4	8	6	6	8
Type	Shell and tube	Shell and tube	Shell and tube	Shell and tube	Shell and tube
Dimensions	77 ft 4 in. × 17 ft 3 in. i.d.	70 ft × 17 ft 6 in. dia.	82 ft × 19 ft dia.	90 ft × 21 ft 6 in.	73 ft 6 in. × 19 ft 6 in.
Shell material	Coltuf 28	m.s.	—	28/32 boiler m.s.	Si-killed C steel
Shell thickness	1⅛ in.	1⅛ in.	—	2¼ in.	1⅞–2½ in.
H.T. area	99,735 ft²	—	1,245,000 ft²	—	1,028,200 ft²
Extended surface	Studded tube	Integron	Integron	Studded tube	Continuous welded fins
H.P. steam temp.	313°C	319°C	373°C	364°C	371°C
H.P. pressure	296 p.s.i.g.	295 p.s.i.g.	756 p.s.i.g.	640 p.s.i.g.	580 p.s.i.g.
H.P. flow	396,000 lb/h	1,110,480 lb/h	1,024,800 lb/h	1,760,000 lb/h	1,144,000 lb/h
L.P. temp.	171°C	316°C	373°C	350°C	349°C
L.P. pressure	48 p.s.i.g.	57 p.s.i.g.	196 p.s.i.g.	171 p.s.i.g.	150 p.s.i.g.
L.P. flow	110,600 lb/h	517,560 lb/h	525,000 lb/h	1,000,000 lb/h	568,000 lb/h
Feed temp.	37.8°C	76.6°C	88°C	72°C	147°C
Condensed feed	687,500 gal, half basin capacity	4×80,000 gal/min	6×45,000 gal/min	6×82,000 gal/min	6 × 54,000 gal/min
Thermal shield	6 in. steel	m.s. 5 in. top 4-in. bottom 1-in. sides	None	6-in. concrete	None
Biological shield	7-ft sides 8-ft top	8 ft 7 in.	9 ft—10 ft	7 ft—9 ft	9-ft side 10½+1½ ft top 6½ ft bottom
Wt. on foundations	33,000 tons	55,000 tons	76,600 tons	—	44,700 tons

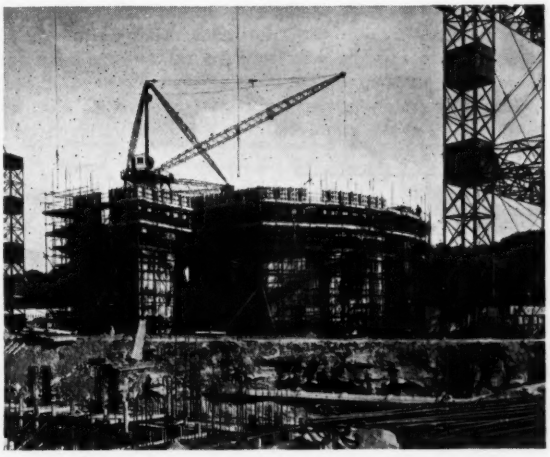
* These and subsequent figures refer to one reactor. † Subject to revision.

N.E. Manufacturing Survey—4

The G.E.C. and Nuclear Developments

By K. J. WOOTTON,
B.Sc.(Eng.), D.I.C., Ph.D., A.M.I.Mech.E.
(*Manager, Atomic Energy Division, The General Electric Co., Ltd.*)

WHEN, in 1954, the Government of Great Britain called upon British industry to undertake the study and development of nuclear energy for power production, **The General Electric Co., Ltd.,** was among the first organizations to be approached. As a result, the G.E.C. Atomic Energy Division was founded and, at the same time, a most rewarding collaboration was established with **Simon-Carves, Ltd.,** experts in the design of steam-raising plant and in the fields of civil and chemical engineering. The work of this joint enterprise was given targets and a time-scale by the announcement, in February, 1955, of a complete British nuclear power programme. At the end of 1956, the South of Scotland Electricity Board awarded the contract for one of the world's first full-scale commercial nuclear power stations to the G.E.C. as main contractors.



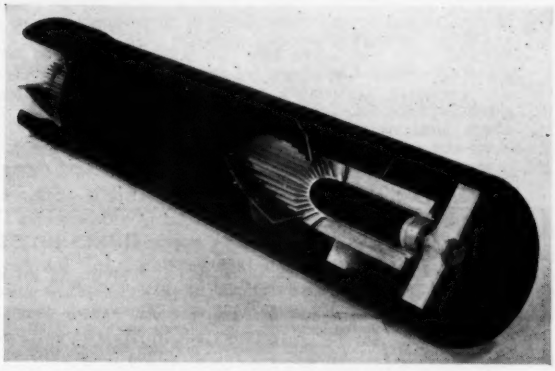
The first reactor under construction at Hunterston.

Constructional work on this two-reactor station at Hunterston, near Glasgow, was at first delayed owing to difficulties in acquiring the site. Work eventually started in October, 1957, and is proceeding according to schedule. The first reactor is due to become critical early in 1961, and the second approximately 12 months later. The whole station, which will have an installed generating capacity of 360 MW, will be fully operational in 1962.

The Hunterston power-station design, in common with the whole British programme, is based on the gas-cooled graphite-moderated reactor using natural uranium as fuel and carbon dioxide as coolant. The recommendation by the United Kingdom Atomic Energy Authority that a British nuclear power programme should initially be based on this gas-cooled system was made after very careful study of the alternatives, and time has shown that the development potential of the gas-cooled reactor was, if anything, underestimated. The rate of advance from Calder Hall, the prototype of this reactor system, has been rapid, and the scope for future development is seen to be very considerable.

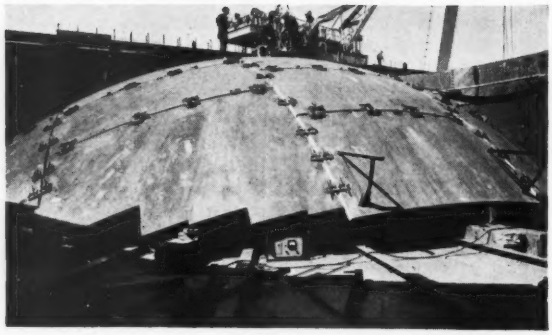
Many countries are now beginning to realize that the design, construction and operation of a considerable number of large, gas-cooled, power-producing reactors in the United Kingdom is building up a fund of experience which is unequalled elsewhere in the world, and that this experience may be most appropriate to the solution of their own power problems. A large part of each of the new designs for nuclear power stations now being worked on in our design offices may be considered "conventional," in the sense that the design has been proved. This we believe to be most important. It is not right or reasonable to expect electricity supply companies, and especially foreign companies, to purchase prototype nuclear power plants.

The rate of development of the gas-cooled reactor has been such that many advances were proved feasible even before the first Calder Hall reactor went critical. Some of these advances, such as the use of steel of increased thickness for the reactor pressure vessel, were natural, and indeed predictable, improvements to a design whose advantage was that it was susceptible to development. However, there was in addition considerable scope for the ingenuity of individual designers in meeting the many problems inherent in the design of a base-load power station of this type. The Hunterston reactors exhibit a number of radical departures from the original basic design and include many unique features which we consider advantageous.



Cut-away view of fuel element in graphite sleeve.

A particularly interesting example is to be seen in the case of the fuel elements which are stacked in vertical channels through the core. In the design evolved by the G.E.C., each canned fuel rod is separately supported in a graphite sleeve so that the weight of the complete stack is



Dome for the bottom section of the first reactor formed ready for welding.

transmitted through the sleeves. The risk of distortion of the lowest rods in a channel at the high operating temperatures is therefore avoided.

This type of fuel element also forms a relatively robust unit in which the actual cartridge is protected by the sleeve during all handling operations. Furthermore, in the unlikely event of a cartridge bursting, the contamination arising from the released fission products would be mainly confined to the sleeve which would, in any case, be discharged with the faulty element. The interposition of the sleeve between the coolant gas stream and the main channel walls allows the minimum temperature of the moderator graphite to be higher than the inlet gas temperature. Thus the build up of Wigner energy can be eliminated without it being necessary to raise the inlet gas temperature above the figure which is desirable from the considerations of steam-cycle efficiency. The replaceable graphite sleeve is also a valuable insurance against the effects of any carbon-dioxide/graphite reaction which might become apparent only after very long-term operation of the reactor.

An additional advantage of the Hunterston fuel-element design is directly associated with another feature peculiar to this station, the arrangements for refuelling the reactor. The majority of reactors of this type are refuelled from above the core. In the case of Hunterston, however, a single machine has been developed which is capable of charging and discharging fuel elements while the reactor is on load, and which operates beneath the reactor. With this machine it is possible to handle all the fuel elements in a channel in a single operation, and this is greatly facilitated by the fact that the graphite sleeves mate together on the " cup-and-cone " principle. This arrangement offers obvious economic advantages and, in addition, enables a discharged stack of elements to be divided into two parts inside the charge machine and recharged in inverted order. This process of " axial inversion " permits a greater average burn-up of the fuel to be obtained for a given maximum burn-up.

A few of the other assets of the bottom-charging system are that it is possible to gain access to any fuel channel from both ends, even with the reactor on full load; no mechanical component other than the fuel elements themselves normally enter the core, thus reducing the risk of damage to the channels; it also minimizes congestion of equipment on the upper face of the concrete shield above the reactor, which already carries control-rod mechanisms, burst-cartridge detection gear and several other items. We feel that it is highly desirable that the control face of the reactor core shall be separate from the charge/discharge face in order to minimize possible contamination of the former which might result from the removal of burst fuel elements or malfunctioning of charge/discharge equipment.

The Hunterston power station is to have an electrical output of 320 MW, more than twice the minimum capacity

La G.E.C.—Simon-Carves a en construction pour la Régie d'Electricité de l'Ecosse-Sud, une centrale nucléaire de 300 MW à Hunterston. Dans cette centrale, le problème des opérations de chargement et de déchargement a été abordé de nouvelle façon, la machine de chargement étant située au-dessous du réacteur, en laissant le plancher de chargement dégagé pour les contrôles et l'entretien. Dans l'article on traite des recherches nécessaires pour l'appui d'une équipe de conception nucléaire en se référant particulièrement aux facilités à Erith.

G.E.C.—Simon-Carves sind bei der Errichtung eines 300 MW Atomwerks in Hunterston für die staatliche Elektrizitätsgesellschaft von Süd-Schottland. Bei diesem Werk ist man von einem ganz neuen Gesichtspunkt an die Konstruktion der Apparatur zur Einbringung und Entfernung des Brennstoffs herangegangen. Die Lade-Maschinen sind unter dem Reaktor angeordnet, sodass die Ladebühne für Ueberwachung und Bedienung frei bleibt. Die Forschungsarbeit, die notwendig ist, um die Gruppe, die den Entwurf des Atomwerkes bearbeitet, zu unterstützen, wird besprochen, wobei besonders auf die Möglichkeiten in Erith Bezug genommen wird.

G.E.C.—Simon-Carves tiene en construcción para el "South of Scotland Electricity Board," una central de fuerza nuclear de 300 MW en Hunterston. En esta central se ha dado consideración en un sentido nuevo al procedimiento de cargar y descargar, estando la máquina cargadora localizada debajo del reactor, dejando el piso de cargado libre para los mandos y para mantenimiento. Se discute las investigaciones necesarias para apoyar a un equipo de diseño nuclear, con particular referencia a las facilidades en Erith.

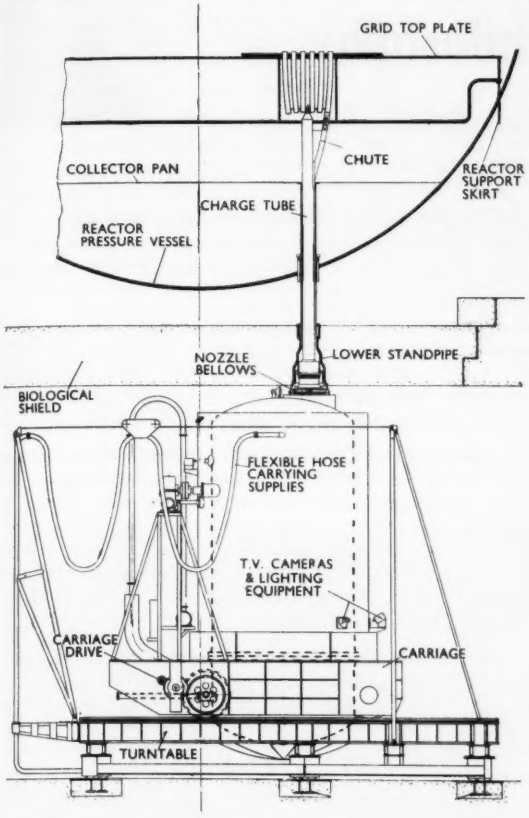
ROLLS-ROYCE, LTD. (page 389)

En association avec Vickers et Foster Wheeler, le groupe dénommé Vickers Nuclear Engineering fut fondé et un contrat fut passé à ce groupe par l'Amirauté Britannique pour la conception d'un sous-marin mû par l'énergie nucléaire. Vickers et Rolls-Royce furent responsables du premier réacteur modéré à l'eau légère à Harwell, le LIDO, et le réacteur naval d'énergie zéro à eau légère NEPTUNE fut conçu et construit par Rolls-Royce. Une section de développement étendue a été établie, et elle jouit de l'appui de ses propres facilités de calculs. Une étude de la conception d'un groupe propulseur pour un navire marchand est actuellement en préparation.

In Verbindung mit Vickers und Foster Wheeler wurde eine Gruppe Vickers Nuclear Engineering gegründet, mit der die Admiralität einen Kontrakt abgeschlossen hat, der den Entwurf und Bau eines mit Atom-Kraftantrieb versehenen Unterseebootes betrifft. Vickers und Rolls-Royce waren für den ersten, mit gewöhnlichem Wasser moderierten, Reaktor in Harwell LIDO verantwortlich und der Marine-Reaktor NEPTUNE für gewöhnliches Wasser und Null-Leistung war von Rolls-Royce entworfen und gebaut. Es ist eine umfassende Entwicklungs-Abteilung eingerichtet worden, die ihre eigenen Rechenanlagen hat. Augenblicklich wird der Entwurf für eine Antriebseinheit für ein Handelsschiff studiert.

En Asociación con Vickers y Foster Wheeler, fué formado el grupo llamado Vickers Nuclear Engineering y se colocó con este grupo un contrato por el Almirantazgo para el diseño de un submarino con propulsión nuclear. Vickers y Rolls-Royce fueron responsables por el primer reactor moderado por agua ligera en Harwell, LIDO y el reactor Naval NEPTUNE de energía cero y agua ligera fué diseñado y construído por Rolls-Royce. Se ha establecido un departamento comprensivo de desenvolvimiento, apoyado por sus propias facilidades computadoras. Actualmente se está preparando un estudio de diseño de una unidad de propulsion para un buque mercante.

which was specified in the original inquiry. Furthermore, less than two years after the contract was placed, the G.E.C. is now prepared to build, in any part of the world, two-reactor stations of the same basic type capable of outputs as high as 800 MW.



Arrangement of bottom-charging machine for Hunterston.

Developments of this magnitude can only be achieved as a result of intensive research, and by the closest co-ordination of the work of pure scientists and engineers of all types. This work must, in every case, be firmly directed towards the achievement of the maximum safety, reliability and economy of the complete power station, and its value can therefore only be judged on a basis of practical engineering feasibility. It was the recognition of this fact that led the G.E.C. to establish the headquarters of its Atomic Energy Division at the Company's heavy mechanical engineering works at Erith, where the experience accumulated during many years of conventional engineering practice was readily available to provide a firm basis for the solution of the problems arising in reactor design.

Research

In addition we believe that only by continuing to invest heavily in both short-term and long-term development projects can Britain maintain her lead in the field of nuclear power production. At Erith our studies range from the proving of special bearings to the testing of complete charge machines, and from experiments on protective coatings for steels to long-term metallurgical studies of beryllium. The work on beryllium is a particularly interesting example of an investment which may or may not bring dividends in the shape of an improved fuel-canning material. This metal,

The beryllium laboratory: working boxes for oxidation experiments.

apart from having a very low neutron-absorption cross-section, possesses high-temperature properties which, by allowing the operating temperature of the fuel elements to be raised, might permit an increase of as much as 100°C in the maximum outlet temperature of the coolant gas. This, in turn, would result in the attainment of improved steam conditions.

A great deal of valuable work is also in progress at other establishments of the G.E.C. and Simon-Carves. At Cheadle Heath, for instance, the Simon-Carves Concrete Research Section is carrying out extensive theoretical and experimental investigations on the possibility of combining the conventional steel reactor pressure vessel and the reinforced-concrete biological shield to form a single prestressed-concrete structure. At the G.E.C. Research Laboratories at Wembley, most valuable work has been and is being done, for example, on the effects of irradiation on the physical properties of graphite and on the carbon/carbon-dioxide reaction.

Research and development work at Erith and in associated laboratories is not confined to plant based on the Calder Hall design, but also includes investigations of other reactor systems which may eventually offer economic or operational advantages either for electrical power generation or for other specialized applications such as marine propulsion.

One promising type is a high-temperature gas-cooled thermal breeder reactor operating on the thorium/uranium-233 cycle. The United Kingdom Atomic Energy Authority has awarded the G.E.C. the contract for a large part of the design and construction of a zero-energy critical assembly which will constitute the first step in the practical development of this new type of reactor. The proposed fuel-element design should permit the use of much higher operating temperatures, probably about 800°C, which would result in vastly improved steam conditions with consequent improvement in operating costs.

This is only one of the many advanced projects which are continuously in progress. However, it should again be stressed that, despite the novelty of much of the work involved, ultimate achievement in any branch of nuclear development for power production arises from the ability to call upon a considerable fund of conventional mechanical, electrical, and civil engineering experience to support a high rate of investment and a generous allotment of manpower in the field of research.

N.E. Manufacturing Survey—5

A.P.C.—The Underlying Philosophy

By J. W. Ashley
(Chief Engineer Atomic Power Constructions Ltd.)

OF the five major nuclear power groups formed in Britain, Atomic Power Constructions Limited, incorporated in December, 1956, is the youngest. Its business is the design and supply of entire power stations both at home and overseas, although in the latter case the company is prepared in certain instances to provide designs and equipment under licence. As the group is constituted rather differently from the other four consortia, consideration is given to the philosophy underlying its administrative structure.

Nuclear engineering involves the synthesis of many aspects of engineering science; heat transfer, metallurgy, control engineering and concrete technology to mention but a few. Each is a specialist field in which the group must be able to draw on the necessary experience; the particular quality of nuclear engineering is that the technological problems are of such complexity and the design considerations are so finely balanced that no independent decision can be taken in a particular field without immediately affecting decisions in other apparently remote fields. Nuclear engineering is, in fact, systems engineering on an extremely large scale and by nature it requires compromise between conflicting claims.

These circumstances require the closest liaison between engineers concerned with different aspects of the work; to facilitate this and to avoid any latent imbalance in the design effort it is desirable that there should be a central design organization both financially and administratively distinct from the member companies and unequivocally possessing ultimate authority for determining the design. Further, in a rapidly advancing branch of technology, design and research go hand in hand. It is desirable, therefore, that basic research facilities shall come directly under the control of the central design organization; in this way the design engineers can feel confident that the experimental programme is planned to answer the right questions and will produce the necessary information on time. Although this may appear no great problem it is, in fact, greater than many would suppose.

Although there is evidence that certain of the other groups may be moving towards the same type of organization, Atomic Power Constructions Limited may fairly claim to be unique in the British nuclear power industry in possessing the form outlined above.

The companies grouped around Atomic Power Constructions Limited are set out below:—

(1) **Crompton Parkinson Limited,** who are electrical manufacturers and engineers of great experience and who will supply principally transformers and switchgear. Cromptons have built some of the largest transformers made in Britain, with capacities up to 120 MVA at 275 kV.

(2) **Elliott Brothers (London) Limited,** which is the largest group of companies in Europe specializing in the design, manufacture and installation of electrical, electronic, hydraulic and mechanical equipment for instrumentation, control and complete automation. Elliott Brothers have unrivalled experience in the automatic logging and data reduction systems which will be an important feature of all future nuclear power stations.

(3) **Fairey Aviation Company Limited,** who, as a result of many years in the aeronautical industry, are able to draw upon a fund of experience in achieving engineering reliability under difficult physical conditions and in the solution of novel engineering problems. Among their achievements are the first aircraft to raise the world air speed record to over 1,000 m.p.h. and the Rotodyne, the world's first vertical take-off airliner. Fairey Aviation have completed numerous contracts for the U.K.A.E.A. including graphite restraints, control rods for power reactors and apparatus for nuclear factories. A very large proportion of fuel element cans used in existing British reactors were manufactured by the company.

(4) **International Combustion (Holdings) Limited,** who bring to the group the manufacturing and field resources required for the construction of boilers and associated equipment. They have very wide experience in the construction of conventional coal-fired steam-raising plant for power stations; a 550 MW boiler unit, the largest known in the world, is to be supplied by them for the Thorpe Marsh power station of the Central Electricity Generating Board. A subsidiary company, International Combustion (Nuclear Applications) Limited, undertakes development research

L'Atomic Power Constructions fut le dernier des grands consortiums à se fonder et à l'heure actuelle des dessins sont en préparation pour la centrale de Trawsfynydd, dont les contrats seront passés par la C.E.G.B. l'année prochaine. L'article traite de l'historique de chacune des compagnies du consortium et aussi des plans de la compagnie pour le développement des centrales d'énergie et de la propulsion.

Atomic Power Constructions ist die Gruppe, die als letzte von den grossen Gesellschaftsverbänden gebildet wurde. Zur Zeit werden die Entwürfe für das Trawsfynydd-Werk vorbereitet, das im nächsten Jahr von dem C.E.G.B. in Auftrag gegeben werden wird. Die Interessengebiete der einzelnen Gesellschaften, die die Gruppe bilden, werden besprochen und ferner die Pläne der Gruppe für Kraftwerke und für die Entwicklung von Antriebsmotoren dargelegt.

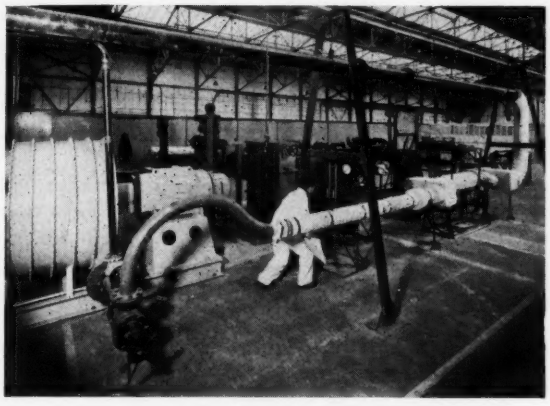
La Atomic Power Constructions fué el último de los grandes consorcios a ser formados y actualmente se están preparando los diseños para la central de Trawsfynydd, los contratos para la cual serán colocados por la C.E.G.B. el año próximo. Se discuten las perspectivas de las compañías componentes y se hace una exposición de los planes de la Compañía para el desenvolvimiento de centrales de fuerzas y propulsión.

and specialized construction in certain aspects of the nuclear field.

(5) **Nuclear Civil Constructors,** a newly established firm which brings together the resources of two of the largest British civil engineering and building contractors, Trollope & Colls Limited, and Holland & Hannen and Cubitts Limited. Both these firms have undertaken major civil engineering works of all types, including work on nuclear plants for the U.K.A.E.A. and on major power schemes in Britain and in other countries.

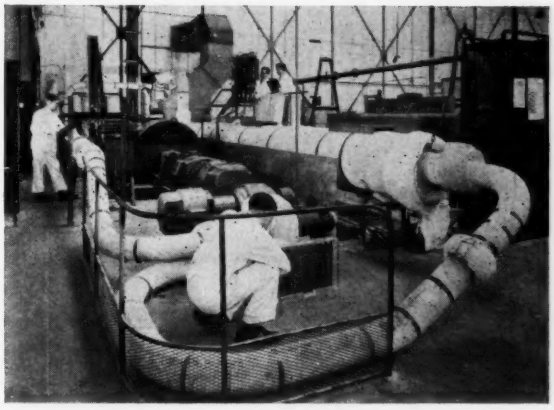
(6) **Richardsons Westgarth & Company Limited,** who are responsible for providing turbo-generators, blowers and condensing plant generally similar to those they already supply for conventional stations. Richardsons Westgarth share with International Combustion, their sister company within the group, the distinction of achieving the highest thermal efficiency of any power station in the United Kingdom—a record which they have held for the past four years. The company is the largest manufacturer of ship propulsion machinery in Britain; its nuclear activities are conducted through a subsidiary, Richardsons Westgarth (Atomic) Limited.

In addition, **Babcock and Wilcox, Limited,** while not a member company, is linked to Atomic Power Constructions, Ltd., by an agreement for the detailed design and supply of reactor pressure vessels, where these are of the steel type.



Research laboratories: atmospheric pressure test rig for fuel element heat transfer tests.

Atomic Power Constructions' laboratories are situated at Heston, on the outskirts of London, and are conveniently accessible from the main offices at 28 Theobalds Road, W.C.1. During the first eighteen months of the company's life it has been necessary to build up a large design and research and development organization. This has naturally involved the expenditure of large sums of money with the effort on research and development alone running at the rate of approximately £500,000 per annum which will tend to increase in the future. Experimental work is at present concentrated exclusively on the engineering development of the graphite-moderated, gas-cooled reactor, although other schemes are, of course, under theoretical consideration. In many ways it may be said that the central problem in reactor design lies in the development of the fuel element and much of the programme is directed to this end. Extensive tests are conducted on atmospheric, pressurized CO_2, thermal cycling and bowing rigs to achieve the optimum heat transfer and mechanical properties. Fuel cans for these tests are provided from within the group by the Fairey



Research laboratories: pressurized CO_2 fuel element test rig.

Aviation Company Limited, whose premises are adjacent to the Research Laboratories.

Metallurgy forms another important aspect of the work of the research laboratories, the creep test facilities, which include a temperature controlled laboratory, being particularly comprehensive. Beryllium machining facilities, already provided by Faireys, are being extended in anticipation of the next step in the engineering development of the gas-cooled reactor, which is likely to be the use of beryllium-canned fuel elements working at higher temperatures.

Experimental test facilities are, however, but one form of supporting service required by the central design organization. Their complement is a computing service and, once again, the comprehensive scope of the activities of the member companies is evidenced by the fact that this service is provided entirely from within the group by Elliott Brothers (London) Limited. Elliotts employ a large special-purpose analogue computer exclusively on work for Atomic Power Constructions. Machines of this type simulate the behaviour of a complete nuclear power station so that variations in the design and operational behaviour of such stations can be tested without having to build them. In addition, digital computers are employed in theoretical studies, and in this case results and programming information are frequently transmitted to and from head office by teleprinter.

In addition to the work carried out directly by Atomic Power Constructions, large extensions have been made by member companies, notably International Combustion Limited and Richardsons Westgarth & Company Limited, in order to accommodate new manufacturing techniques and to increase the existing production capacity.

Whilst for the time being the company is working mainly on large land-based power stations it also carries a small group looking at marine type reactors and other applications so that an overall picture of the nuclear energy field is obtained.

Such is a brief outline of the organization which makes Atomic Power Constructions Limited a forceful contender in the nuclear power generation field. The company is currently tendering for stations to be built for the C.E.G.B. at sites in North Wales and in Kent. For overseas inquirers it is ready to submit preliminary estimates of capital and operating costs for nuclear power stations of various output capacities, to undertake preliminary examination and geological survey of projected sites and to give full advice on the utility, safety and operation aspects of nuclear power stations.

N.E. Manufacturing Survey—6

Plans and Projects of Hawker Siddeley N.P.C.

By E. P. HAWTHORNE
(Chief Executive, Hawker Siddeley N.P.C.)

FORMED in January 1956, Hawker Siddeley Nuclear Power Co. Ltd., has developed to a stage where it now has a total staff of approximately 250, consisting of nuclear physicists, mathematicians, engineers, chemical engineers, metallurgists, chemists, instrument engineers, and control engineers etc., together with drawing office and machine shop staff. The Company includes all the personnel required for the design of a complete reactor system, whether for power generation, ship propulsion or purely as a source of heat and has limited manufacturing facilities designed for the production of reactor equipment and other specialized items.

The Company is backed by the other companies of the **Hawker Siddeley Group** and is supported by the **John Brown Group** of companies through the medium of Hawker Siddeley John Brown Nuclear Construction Ltd. which is owned equally by Hawker Siddeley Group Ltd. and John Brown and Company Ltd. There are about 100 operating companies, employing nearly 100,000 persons, associated with the two groups whose products include all the conventional equipment required in propulsion, power production and heat generating plant. The interests of these companies extend to Canada, Australia, Africa and India.

Hawker Siddeley Group Companies have earned a high reputation in the aircraft, Diesel engine, railway transportation and light, medium and heavy engineering fields; in the specialized field of electronics and in the manufacture of equipment for electrical generation and distribution. John Brown and Company Ltd. are well known as shipbuilders. The products of their associate companies include steam and Diesel marine propulsion machinery, large land boilers for central power stations, instrumentation and comprehensive plant engineering, particularly in the oil refining and chemical industries.

The activities of the Hawker Siddeley Nuclear Power Company fall into three main categories. Project studies, design and construction of in-pile and out-of-pile experimental facilities, and research work in the physics, metallurgical and material fields.

Projects

The Company is especially interested in comparatively small-sized reactors having a thermal output of from 50 to 200 MW and upwards. The liquid metal fuelled reactor was initially studied and project evaluations were carried out both for Harwell and on a private venture basis of various types of internally and externally cooled LMFRs. As mentioned below many materials for use in this reactor system have been tested in the Company's metallurgy department. The results of these studies have been incorporated in current designs such as that for the internally cooled reactor system in which the fuel is contained in graphite cans of special design (Figs. 1 and 2). At present, however, it is felt that the development period of this kind of reactor is probably very long, and attention is being focused more on the technological problems of liquid fuels. In the meantime, the Company is studying alternative reactor systems having a shorter development period.

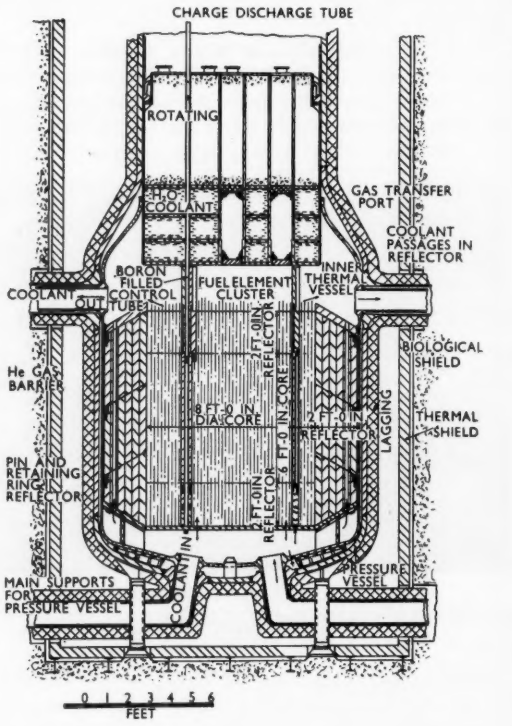


Fig. 1.—Section through liquid metal cooled LMF reactor

Project studies have been made of gas cooled graphite moderated reactors both for power generation and ship propulsion (for which they were found unsuitable) and these were examined side by side with liquid and gas cooled heavy water moderated reactors of different mechanical constructions. With calandria type gas cooled systems it was thought essential that the whole core vessel should be removable for replacement or repair if any heavy water leakage developed (Fig. 5). The size of such a system is limited, however, by the maximum diameter of the flange which can be incorporated in the pressure vessel. To obtain a reasonable output from this system a new fuel element design was required and this is being investigated now. More recently the Company has been examining the

possibilities of the organic moderated reactor for propulsion, power and heat generation.

To assist in carrying out evaluations tape editing equipment is employed, in conjunction with one of the Hawker Siddeley Group's three digital computers. Additionally an analogue computer facility is being built up for the reactor kinetics and control group to solve the dynamic equations of an overall nuclear power system. This facility has in operation at present a neutron kinetics section which will solve the reactor equations using up to six delayed neutron groups and five photo neutron groups present in heavy water moderated systems and these can be given mean lifetimes from 10^{-3} to 10^{-8} sec. The maximum rate of change of δk determinable is 1% per second and the minimum is less than 5×10^{-7}% per second. The amplifier circuit drift is less than 50 μV per day. Two general purpose computing units will be added to solve the equations of the conventional equipment items of a complete nuclear power plant. These computer units will be marketed.

The Company's design facilities have been used for the general and detail design of all experimental facilities and rigs constructed for the various departments. It has also gained experience in the design of in-pile and out-of-pile experimental facilities and loops for various sections of the United Kingdom Atomic Energy Authority, and these include a loop for the determination of mass transfer in sodium systems under irradiation with both fissile and non-fissile specimens and irradiation facilities for high temperature gas cooled fuel element testing.

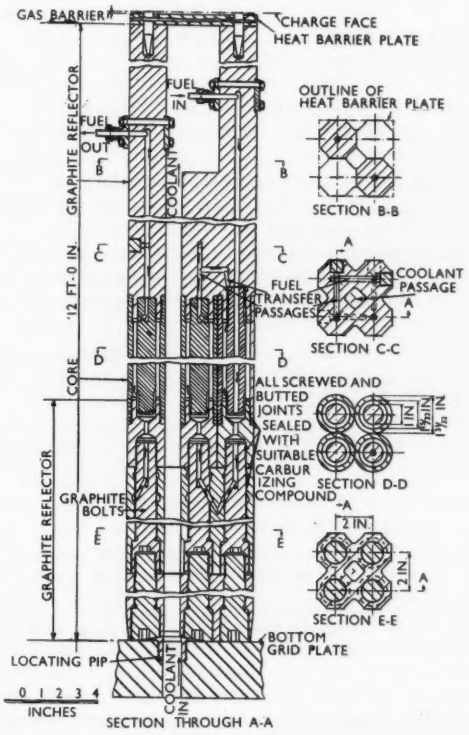


Fig. 2.—Details of LMF reactor.

The manufacturing facilities have been heavily engaged on the production of equipment for various test facilities including the construction of specialized stress and creep machines and they have produced various specialized items under contract such as isotope carriers and source holders.

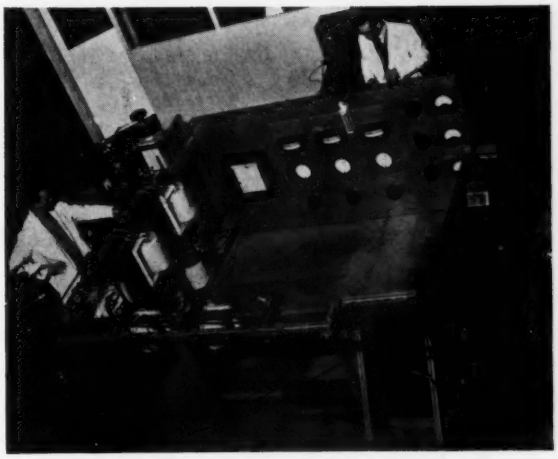


Fig. 3.—Thermal syphon liquid bismuth mass transfer loops which have operated for 5,000 to 7,000 hours.

The test facilities indicate the wide range of interests of the Company and these include a pumped liquid bismuth loop for studies on heat transfer and mass transfer characteristics of this material at temperatures up to 600°C. A special gas bearing pump is used for the bismuth circulation. A rig is in operation under contract to Harwell in which the maximum temperatures to which fuel elements will rise can be determined for various emergency shut

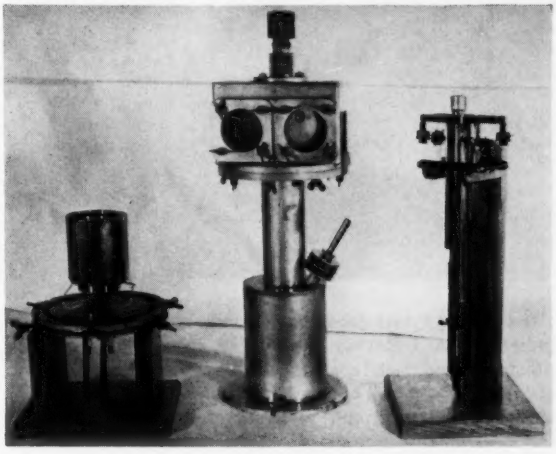


Fig. 4.—Components of a creep machine designed by the company for work in liquid metals.

down conditions of gas cooled heavy water reactors, and there is in course of construction a high pressure gas heat transfer rig. In this it will be possible to determine the heat transfer characteristics of various types of fuel element or fuel element bundles in gases such as carbon dioxide and helium or hydrogen at pressures of up to 40 atmospheres and gas outlet temperatures from the fuel element channel up to 600° or 800°C. Also under construction is a pumped fused salt rig in which will be tested various types of instrument for flow measurement, level indication and pressure measurement in these difficult conditions at temperatures up to 550°C. A further facility which is now in operation is a high temperature physics laboratory which will enable discharges of from

1-2 MA to be achieved for testing materials and equipment etc., for use in fusion experiments.

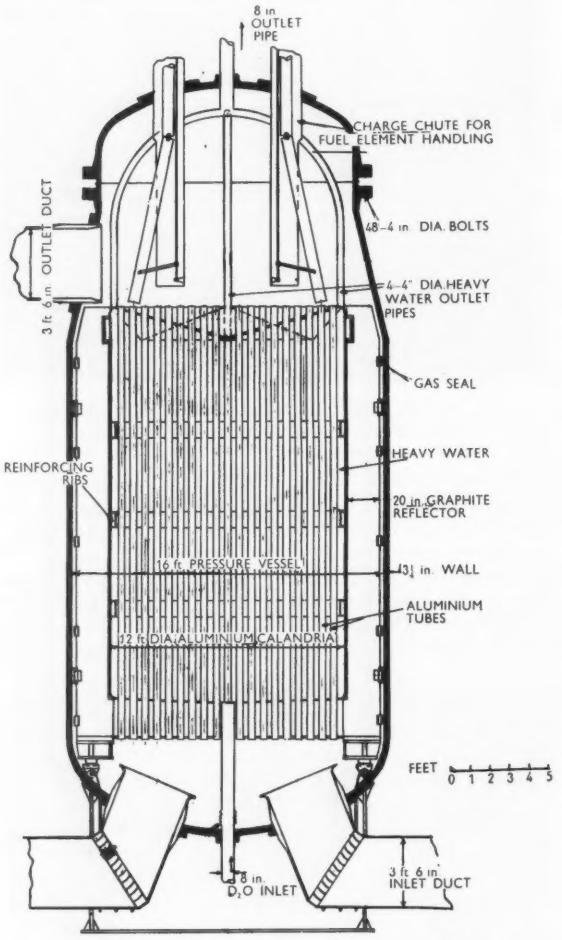


Fig. 5.—Section through heavy water reactor.

The metallurgical department has been employed in the studies of the behaviour of various materials in contact with the liquid metals, fused salt and gases. Much work was initially carried out on the compatibility of various steels with liquid bismuth at temperatures of up to 550°C, in capsules and thermal syphon loops. The effect of various corrosion inhibitors was also examined, and these tests were extended to thermal syphon loops. One of the most interesting loops has been plated internally with tantalum and contains liquid bismuth with magnesium deoxidant and uranium. These latter loops have been operating now for between 5,000 and 7,000 hours with no sign of plugging. The tests were further backed up by stress corrosion and creep tests in liquid bismuth on the most suitable steels. Similar work with liquid lithium has just been started.

Further work has been carried out on the corrosion rates of various magnesium and aluminium alloys in high purity water to simulate conditions in heavy water reactors. The oxidation rates of metals such as niobium at temperatures up to and in excess of 1,000°C in various gaseous atmospheres are regularly determined in a batch of 14 specially constructed furnaces. These are also employed for studies on the interactions of graphite with various gaseous atmospheres.

These specialized facilities are backed up by the normal general metallurgy laboratory equipment for strength and hardness testing, specimen polishing and etching, microphotography and X-ray diffraction work, as well as by one of the finest metallurgical analytical laboratories in the country equipped with a spectrophotometer and square wave polarograph of exceptional sensitivity. The latter has been used in connection with water corrosion for the determination of some ions at concentrations down to one thousandth of a part per million. Special techniques have been developed for the estimation spectrophotometrically of impurities in bismuth down to a few parts per million. These analyses for iron, nickel, chromium, zirconium and uranium are carried out now as a matter of routine. An extension of the technique will allow thorium, aluminium, tin, manganese etc., to be similarly determined.

The Company is now planning to exploit the research reactor market and to this end a model of the "Jason" reactor is being displayed on Stand No. 141 of Hawker Siddeley John Brown Nuclear Construction Ltd. at Geneva. This reactor is developed from the Argonaut reactor produced by the Argonne National Laboratories for post-graduate training and studies in reactor technology.

The Hawker Siddeley Nuclear Power Company plans to extend present available facilities so that it can go ahead more readily to its ultimate aim of designing commercial reactors for propulsion, power and heat generation and the application of acquired techniques in other industrial fields.

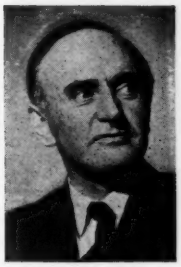
La Hawker Siddeley Nuclear Power Company qui est aussi associée au John Brown Group s'intéresse particulièrement aux groupes propulseurs. Au début, les travaux se concentrèrent sur les réacteurs à combustible métal liquide et un nombre d'équipements et de boucles de transfert de chaleur ont été construits pour l'A.E.A. Toutefois, le LMFR est considéré comme un projet à long terme et des dessins ont été établis pour une gamme de réacteurs à l'eau lourde refroidis au gaz. En outre, des facilités de recherches très étendues ont été crées pour des travaux sur le transfert de la chaleur, le fluage du métal, etc.

Die Hawker Siddeley Nuclear Power Company, die mit der Gruppe John Brown assoziiert ist, hat ein besonderes Interesse an der Entwicklung von Antriebseinheiten. Im Anfang konzentrierte sich die Arbeit auf mit flüssigem Metall arbeitenden Reaktoren und es wurden eine Anzahl von Einrichtungen und Rohrschleifen zur Wärme-Uebertragung für die A.E.A. gebaut. Der LMFR (mit flüssigem Metall als Brennstoff arbeitender Reaktor) wird jedoch als ein Projekt auf weite Sicht angesehen, und Entwürfe sind deshalb für eine Reihe mit schwerem Wasser arbeitende gas-gekühlte Reaktoren gemacht worden. Ausserdem sind umfassende Forschungs-Einrichtungen vorgesehen worden, um Wärmeübertragung, Kriechen von Metall usw. zu untersuchen.

La Hawker Siddeley Nuclear Power Company que está asociada con el Grupo John Brown está particularmente interesada en unidades de propulsión. Inicialmente, los trabajos fueron concentrados sobre reactores de combustible de metal liquido y se han construido varios aparejos y lazos de transferencia de calor para la A.E.A. Sin embargo, la LMFR se considera como un proyecto de largo término y se han elaborado diseños para una serie de reactores de agua pesada con enfriamiento por gas. Además, se han ideado y preparado facilidades comprensivas para trabajo sobre la transferencia de calor, escurrimiento de metales, etc.

N.E. Manufacturing Survey—7

Mitchell Engineering Ltd. and the BWR



By G. GORDON JACKSON
(Manager, Nuclear Power Division, Mitchell Engineering Ltd.)

THREE years ago the London engineering company **Mitchell Engineering, Ltd.,** arranged to work in partnership with the Atomics Division of the **American Machine and Foundry Co.** of New York, in the construction all over the world of nuclear power plant. It was the first arrangement of its kind between a British and an American firm.

Mitchells, over many years, have built up a great deal of experience, not only in the field of manufacturing boilers and other items of power station plant, but also in the actual construction of power stations. A.M.F. Atomics, on their part, have for some time been engaged in the design and production of nuclear power plant, and the two companies are now working in close harmony after three years' experience of technical co-operation.

The partnership has recently been strengthened by the inclusion of the **General Nuclear Engineering Corporation** as consultants.

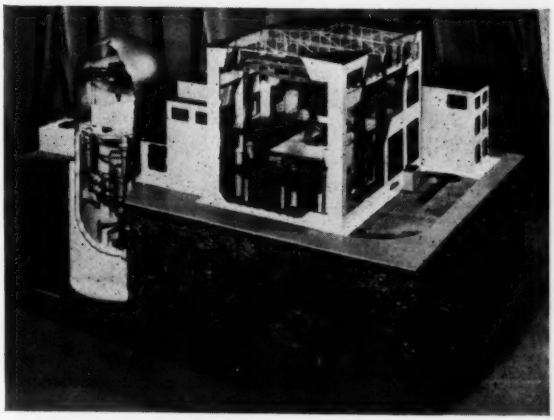
The two companies, having both made extensive research into the varying types of nuclear power production, decided to specialize in the boiling-water reactor type. This decision was reached after making close studies of gas-cooled, liquid-metal-cooled and pressurized-water systems. The boiling-water system was chosen as it proved to possess very real advantages over the others, by its relative ease of construction, its safety, its efficiency, its potential in terms of the power output increases and its economy.

Boiling-water Reactors

An experimental boiling-water reactor in the United States has recently developed over three times its designed power level, even though the full-sized core has not yet been installed. Work has, therefore, gone ahead in designing a plant which could use this system to its fullest extent.

It has many advantages and one of the most important is that it can be operated, controlled and maintained by technicians rather than by scientists, which is a valuable aspect if installations are situated in remote areas. One reason for the simplicity of operation is the low operating pressure/high temperature ratio—for example, in the 17.5 MW reactor, the operating temperature is 534°F, but the pressure is only 915 p.s.i.a. Further, heat exchangers are not essential although, of course, they can be provided if desired. If they are installed, the reactor can provide steam for process work and space heating as well as for electrical power generation. Mitchells are at the present moment engaged on an extensive research programme into the further development of such installations, and have constructed a heat exchanger test rig to measure heat transfer rates under operating conditions at pressures up to 2,000 p.s.i.g. with fluid mass flows, similar to those experienced in water-moderated reactor power plants.

Yet another advantage of the BWR from the point of view of simplicity of operation, is that pumping power requirements are comparatively low and pipework sizes proportionally smaller. This is because the reactor obtains its energy pressure mainly by a change of state of the circulating fluid. Sub-cooling of the primary water is provided to reduce the average vapour fraction in the core, and also to reduce the water re-circulation rate.



Model of a 17.5 MW closed cycle boiling water reactor plant.

The reactor also possesses its own self-regulating safety device in the steam bubbles formed in the core. This controls the reactivity of the core so that if a sudden transient should occur, the extra bubbles formed will reduce the reactivity and automatically shut down the reactor.

Four Sizes

There are four different sizes of reactor which Mitchells-A.M.F.-G.N.E.C. build. The first is the 17.5 MW reactor, which is designed to provide an economic nuclear power plant for sites where a small-scale electrical generating or steam-producing plant is needed. It is a compact design and one of its most important features is the ease of erection and installation in areas which are remote from ordinary facilities. It has a gross thermal output of 58.5 MW and produces steam at the rate of 220,000 lb/h at a pressure of 915 p.s.i.a. The reactor core is contained in a steel pressure vessel and this in turn is surrounded by a layer of insulation and is housed with other equipment and controls in a gas-tight building.

Great care is taken to incorporate special safety measures. These include a special design of the reactor core and

spring-assisted control rods. In an extreme emergency, boric solution can be injected into the reactor in a matter of seconds.

The next two sizes of reactor are the 30 and 70 MW units which are of similar design. These two reactors can provide for the generation of steam at 1,200 p.s.i.a. and permit a wide measure of power output control through throttling the secondary steam generator. In the case of the 30 MW reactor, the steam is produced at a rate of 283,000 lb/h and of the 70 MW at 601,000 lb/h.

The biggest station at present available from Mitchells-A.M.F.-G.N.E.C. is the 140 MW, which consists of two 70 MW reactors installed as multiple standard units. Such a design has all the economic advantages over a very large single unit, as two 70 MW units pose no very large problems of fabrication or transport. Further, a multiple unit has greater flexibility, and is better equipped to accommodate wider fluctuations in power demand. However, if demand and conditions of transportation and installation are such that a single large reactor would be more efficient, then Mitchells-A.M.F.-G.N.E.C. are fully equipped to provide designs for such an installation. On some sites it may be more economical to replace conventional boilers and retain the existing turbine cycle; this can easily be effected as designs provide for the optional incorporation of a separately fired super-heater.

Fuel

Slightly enriched uranium fuel used in Mitchells-A.M.F.-G.N.E.C. reactors is at present only available from U.S. sources and the supply is subject to a bilateral agreement between America and the country concerned. Such agreements exist at the present time between the U.S.A. and 13 countries, and spent fuel is returned to America for reprocessing.

However, enriched uranium will soon be available from other sources, including the fuel pool of the United Nations International Atomic Energy Agency, and some Euratom countries will eventually be in a position to provide the same service.

Mitchells

Mitchells have a wide experience of engineering installations and construction projects, covering every aspect of steam and electrical generation; their present commitments range from conventional power station construction to large-scale hydro-electric schemes and the building of nuclear power plant for the Atomic Energy Authority. In addition to the design and supply of boiler units, they also provide a complete service for power station construction.

The most important current nuclear contract is for the main civil engineering works, including foundation work, the building of four reactors, four cooling towers and associated heat exchangers and the turbine hall at the Atomic Energy Authority's Chapelcross power station, Dumfriesshire. Another contract, at Capenhurst, near Chester, is for pipework, process plant and equipment, and six cooling towers. A third contract is for pipework and other plant at Springfields, and at Dounreay, Mitchells are supplying and installing engineering equipment for the chemical laboratory associated with the fast breeder reactor.

A.M.F.

Among the early achievements of the company was the design, development and complete installation of all the mechanical equipment including fuel handling and reactor control for the A.E.C. Savannah River Project, which is one of the largest nuclear installations in existence. Today, they have 16 reactors completed or in various stages of design or construction throughout the world and are leading designers and manufacturers of research reactors.

Among the other projects which A.M.F. Atomics have handled are the designs for control mechanisms and systems, and fuel-handling equipment, for such power reactor systems as the Fast Breeder Reactor, developed by A.P.D.A., the U.S. Navy Submarine "Sea Wolf," the Pennsylvania Advanced Reactor, and many others. They have also carried out studies for nuclear fuel automatic processing equipment for the U.S.A.E.C.'s Oak Ridge National Laboratory.

The reactor cores in the Mitchells-A.M.F.-G.N.E.C. reactors have been designed by Dr. Walter Zinn, President of the General Nuclear Engineering Corporation in Florida.

Among the many advantages offered by this Anglo-American association are that first the majority of the cost is in sterling, thus making the development of nuclear power in the Commonwealth a very real proposition. Further a large amount of the conventional engineering is sub-contracted to firms in the customer's country, as Mitchells are not tied to any consortium, and yet another is that Anglo-U.S. training of reactor operating personnel as well as practical construction experience gained by the foreign firms is greatly to the advantage of overseas countries.

La Mitchell Engineering est l'entrepreneur civil principal pour la centrale d'énergie nucléaire de l'A.E.A. à Chapelcross qui comprend quatre réacteurs, analogues à Calder Hall. Ce fut la première compagnie du Royaume-Uni à s'associer avec une maison américaine, la AMF Atomics, qui utilise les services de la General Nucleonic Engineering Corporation pour la conception des noyaux. Le groupe offre une gamme de réacteurs jusqu'à 140 MW basés sur le principe de l'eau bouillante pressurisée. Des surchauffeurs chauffés à l'huile peuvent aussi être incorporés dans les dessins pour se valoir de l'équipement de turbines en existence.

Mitchell Engineering ist die Baufirma, die in der Hauptsache das Atom-Kraftwerk in Chapelcross für die A.E.A. baut, das vier Reaktoren umfasst, die ähnlich werden wie Calder Hall. Mitchells war die erste britische Gesellschaft, die sich mit einer amerikanischen Firma verband, AMF Atomics, die sich von der General Nucleonic Engineering Corporation die Konstruktionen des Kerns machen lassen. Die Gruppe offeriert Reaktoren in Grössen bis zu 140 MW, die auf dem Prinzip des Siede-Druckwasser-Reaktors basieren. Oel-gefeuerte Ueberhitzer können ferner bei der Konstruktion eingebaut werden, um die Vorteile auszunutzen, die die Verwendung existierender Turbinenkonstruktionen bietet.

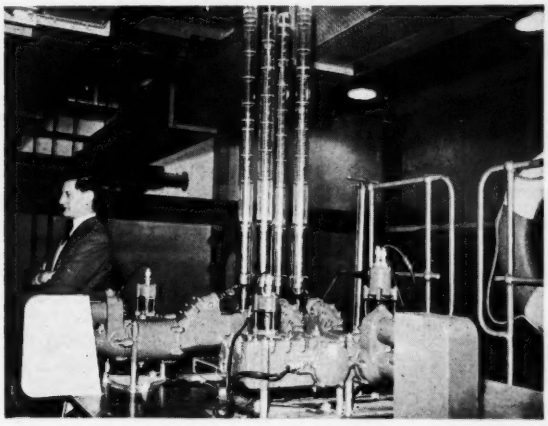
La Mitchell Engineering son los principales contratistas civiles de la central de fuerza nuclear A.E.A. en Chapelcross, la que comprende cuatro reactores, similares a los de Calder Hall. Mitchells fué la primera compañía del Reino Unido a asociarse con una firma norteamericana, siendo ésta la AMF Atomics, que emplean a la General Nucleonic Engineering Corporation para los diseños de núcleos. El Grupo está ofreciendo una serie de reactores hasta 140 MW basados sobre el principio de agua hirviente presurizada. También se pueden incorporar en los diseños supercalentadores a base de aceite, para aprovechar el equipo de turbinas existente.

N.E. Manufacturing Survey—8

Rolls-Royce Activity in the Nuclear Field

By S. G. BAUER, Ph.D.

THE basic science of nuclear reactors was largely completed during the last war, but both physics and technology experience was limited to low temperature reactors designed for experimental work and the production of plutonium. In the early post-war years development gradually turned to the problems of power reactors and in 1954, when **Rolls-Royce** first entered the nuclear field, the scientific base was well developed and the technology of some reactor systems was already well advanced. It was evident at the time that the main challenge in the field had shifted to engineering and it seemed therefore logical that a firm which had long made its name by first-class engineering of the greatest possible reliability and which was accustomed to expensive development work on a large scale should be in a position to make a useful contribution to nuclear engineering.

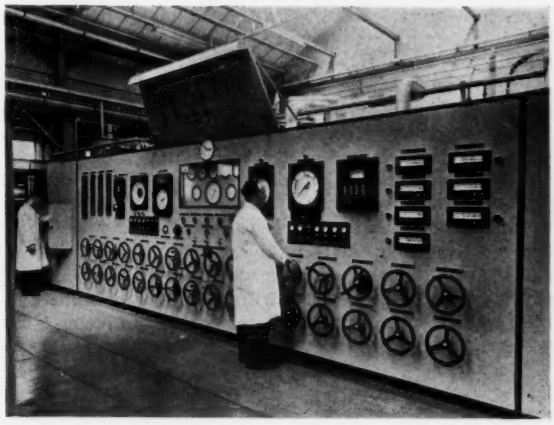


The control gear for LIDO.

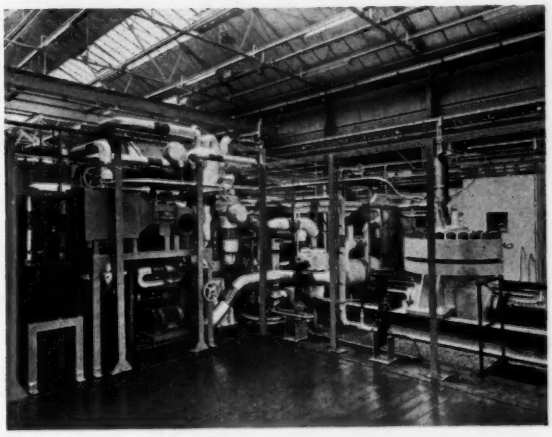
Many projects were investigated while the team grew and got into its stride. Clearly no firm in this country could find the resources to develop and build an experimental reactor by itself nor hope to recover from future customers the money so spent. The field of large-scale power stations seemed to involve a different class of engineering experience which moreover was already well covered by teams familiar with power station design.

The aircraft reactor field, which naturally appealed, obviously needed a vast amount of technological development, much of it of a radioactive nature, before detailed engineering design work could be of any real use. In view of the very uncertain future of nuclear propulsion for aircraft it was not possible to invest large sums of private capital in its development. With these conditions in mind the work of the Rolls-Royce nuclear team was therefore directed towards marine propulsion on the one hand and the design and manufacture of experimental reactor equipment for the A.E.A. on the other.

In 1956 the Admiralty decided to go ahead with the design of a nuclear powered submarine and an association was formed under the name of **Vickers Nuclear Engineering Limited** in which **Vickers, Foster Wheeler** and Rolls-Royce joined forces to design and build first a prototype and later a submarine.



(Above and Below) PWR control rod test facility at Derby.



LIDO, the first light water moderated reactor at Harwell, designed among other things to develop reactor shields which are an essential item for a marine reactor, was designed and built by Vickers in association with the A.E.A. and the control rod gear was designed and made by Rolls-Royce.

NEPTUNE, a light water zero energy reactor, was designed and built by Rolls-Royce for Harwell for the testing of reactor core assemblies of enriched fuel in light

water in connection with the submarine reactor programme. Neptune uses demineralized water at atmospheric pressure as moderator and is designed to allow the rapid assembly of various sizes, shape and composition of cores. The reactor tank imposes a maximum core size limitation well in excess of expected power reactor dimension and, to extend the range of investigations, provision has been made for external heating of the moderator to about 90°C. A cooling circuit is incorporated which shortens the heating and cooling cycle to an acceptable time, although no cooling is necessary while the reactor is in operation, as the power of a few watts is adequate for experimental purposes. The reactor, which went critical in November, 1957, has an entirely novel form of control gear which will be demonstrated in Geneva during the forthcoming international conference.

In the submarine reactor programme at the Derby Works the large joint team of physicists and designers have the support of a nuclear development laboratory including, among other things, a high pressure water heat transfer loop rated at 5 MW in addition to the extensive computing and development resources of the Aero Division.

Propulsion reactors differ from large power station reactors in that they have to follow the rapid load variations imposed by manœuvring. The high ratings required from compact reactors involve difficulties from xenon poisoning with the result that a very substantial amount of excess reactivity has to be available and under control. If satisfactory manœuvring is to be attained the reactor and the steam machinery have to work as one integrated unit so, with the large excess reactivity available, the safety and stability of the power plant is a matter of some concern. The study of the associated control problems is far too complex to be undertaken by hand calculation and an analogue computer has been developed and built by Rolls-Royce specifically for the detailed study of propulsion reactor power plant stability and control problems. This computer will also be available for demonstration at Geneva.

The original nucleus of the Rolls-Royce team grew rapidly with the commitment to the full scale submarine reactor project and outgrew its organization as well as its office space. It was therefore a natural development to hive off this project on its own and reorganize it in the same way as the design and development of a new aero engine model is organized within the general management plan of the firm. When this step was taken an advanced project party was retained to look into the future activities of the firm in the nuclear field.

Apart from continuing work on the design and manufacture of "sophisticated" reactor experimental gear for the A.E.A. the advanced project party has concentrated over the last year or so on further marine reactor studies. Much experience has been gained in the past in the use of extensive digital computing procedures in reactor physics and engineering design and the current studies are based on combining this physics and computing experience with the firm's traditional engineering skills in investigating the best results which could be achieved with already established reactor technology. These studies are primarily concerned with nuclear power plants for tankers which might hope to have an economic future while at the same time being acceptable to marine engineers.

It has often proved in nuclear engineering that ready judgments between different reactor systems can be misleading. Rolls-Royce have therefore undertaken to study, with the active help of Foster Wheelers and Vickers, at least one particular marine reactor system in sufficient detail that reasonably accurate cost, weight and performance estimates can be obtained and, it is hoped, ultimately compared with similar data produced by other people's studies of other systems. It is hoped that this work will help the Authorities, who must soon make a choice, to decide which is the best marine propulsion system to pursue on a national scale.

(*Translations page* 380.)

N.E. Manufacturing Survey—9

Head Wrightson Processes Ltd.

ALTHOUGH Head Wrightson, Ltd. is a member of the Nuclear Power Plant Co., Ltd., its associated company, Head Wrightson Processes, Ltd., exists independently as main contractors for heavy water research reactors, of which no fewer than six have been constructed, or are in course of construction; DIDO, PLUTO, DMTR, HIFAR, DR3 and a further unit not yet named.

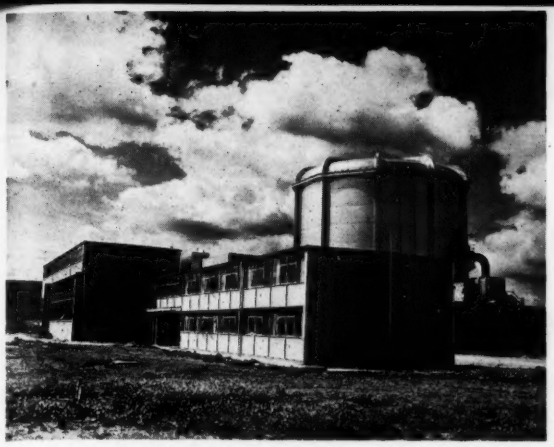
DIDO, the first of the series, was developed by an A.E.R.E. team working in conjunction with the Ministry of Works and Head Wrightson Processes, Ltd. The reactor design was based on (and strongly resembles) the American CP5 at Argonne, but has a considerably higher flux density, the maximum flux being approximately 10^{14} n/cm², sec, this being achieved with an operating power of 10 MW.

PLUTO and DMTR are, of course, similar to DIDO with the exception of the experimental facilities, there being four large straight-through horizontal facilities, suitable for large loops, rather than a multiplicity of smaller facilities.

HIFAR, the Australian reactor, which diverged on January 28, 1958, and has since been operational at its full design power after only a short commissioning period, is installed at Lucas Heights, Sydney. It is similar to DIDO, as is also the unnamed reactor which is being constructed for Land-Nordrhein-Westfalen for the Federal German Republic's research station which will serve the universities of Aachen, Bonn, Cologne and Muenster. DR3, the reactor under construction for Denmark, is of the PLUTO type, for materials testing.

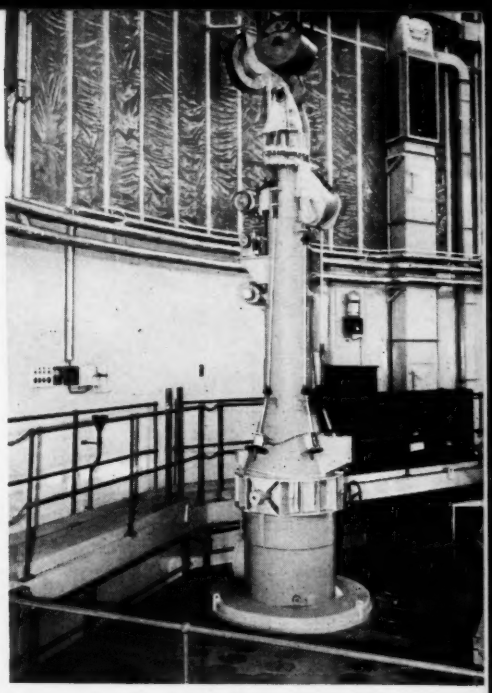
For those wishing to refresh their memories regarding details of design, the following articles have appeared in *Nuclear Engineering*. Engineering aspects of DIDO (January, 1957) and No. 8 in the "World's Reactors" series. DMTR was described in the Dounreay feature in July, 1957 and PLUTO in December, 1957. PLUTO also appeared as No. 16 in the "World's Reactors" series, in April, 1958, which also contained a comparison between the experimental facilities of all the six reactors for which Head Wrightson Processes, Ltd., were responsible.

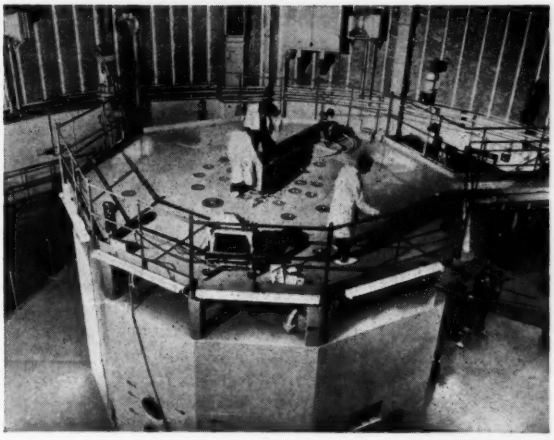
(*Translations page* 395.)



(Left) An external view of PLUTO.

(Right) The fuel element changing flask for DIDO with built-in helium cooling.

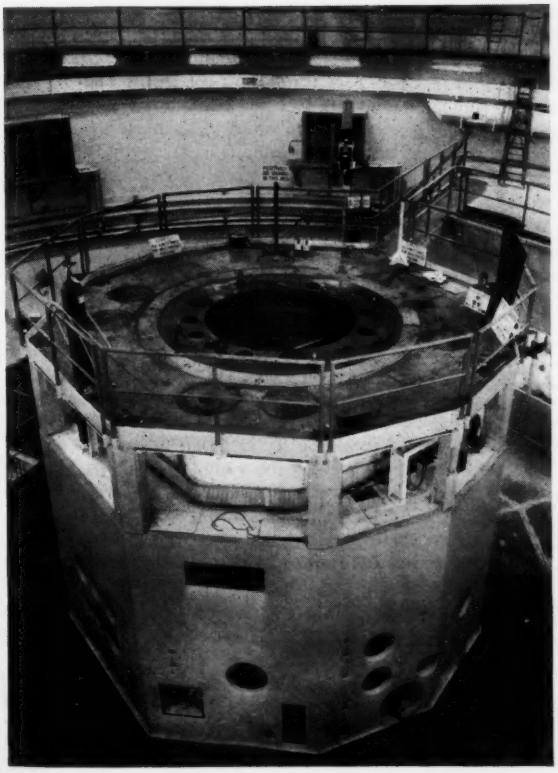




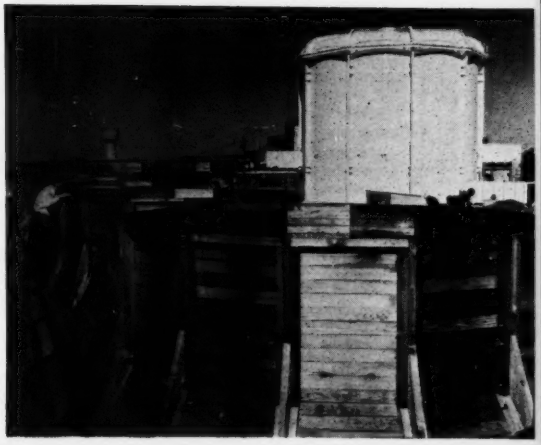
(Left) General view of top-plate of DIDO.

(Below) The cooling towers for PLUTO.

A general view of HIFAR before commissioning.



An external view of HIFAR from the top of the cooling towers.



N.E. Manufacturing Survey—10

The Small Pressurized Water Reactor

By **H. S. PROSSER,**
B.Sc., M.I.Mech.E., M.I.E.E.
(Humphreys & Glasgow Ltd.)

THE major industrial nations of the world have developed complex electricity power grids and networks which require generating units of size of the order of 100 MW upwards, but there are many other countries whose industrialization has not reached this stage and who are, therefore, interested in units of much smaller size. In addition, large industrial firms are not infrequently interested in acquiring their own plants for the generation of electricity or steam, or a combination of both.

There is thus a potential demand for small nuclear stations if these can be made economical, a demand which cannot be met by any design of plant at present commercially available from British sources, owing partly to the fact that these small plants utilize enriched uranium which is not available for power reactors in this country. In the U.S.A., however, enriched fuel is relatively plentiful and considerable experience has been gained in the design and construction of such nuclear plants.

For this reason, and to enable British industry to participate in the construction of small nuclear plants, **Humphreys & Glasgow,** who have had considerable experience in the handling of large engineering projects, announced, in January, 1957, an agreement with **ALCO Products Incorporated,** of New York, to engineer and market power stations incorporating their reactor designs in all countries of the world outside the North American Continent. This agreement enables Humphreys & Glasgow to offer nuclear power stations of small output employing equipment which may be manufactured either in the United Kingdom or in the purchaser's country, which offers considerable benefits in reduction of dollar payments and in the overall contract price.

ALCO were awarded in 1954 a contract from the U.S. Army to design and construct the Army Package Power Reactor (the APPR-1) near Washington, D.C. This was the first fixed-price, guaranteed performance contract to be awarded for a complete nuclear plant, and its successful completion was a major advance in the field of nuclear engineering. This plant, which has a gross output of 2,000 kW and is of the pressurized-water type, was commissioned in April, 1957, and in its first year of operation has generated over 10 M kWh in spite of being on a training programme for Army personnel which necessitates frequent start-up and shut-down operations. Confidence in ALCO has been demonstrated by the recent award to them of a contract to supply a further reactor for Alaska, the APPR-1A, having an output approximately double that of the APPR-1. Both of these reactors have plate-type fuel elements in which stainless steel is used as a cladding for a matrix of uranium oxide having an enrichment of over 90% in the U^{235} isotope.

For general commercial use, however, a design of reactor is available using uranium oxide clad in stainless-steel tubes and having an enrichment of only 4%. The plant on which design work has been concentrated is a reactor having a thermal output of 50 MW, which is able to produce 12.5 MW of electricity when employed for electricity generation. It is expected that outputs in the range of 2-20 MW of electricity will be available in the future or, of course, comparable thermal outputs. Construction of the nuclear and conventional equipment can be performed in the United Kingdom, although it is realized that where the plant is being installed in a highly industrialized country, the purchaser will require as much as possible to be drawn from local resources.

The design of the 50 MW (thermal) nuclear generating unit follows, in principle, the techniques developed from experience gained with the APPR. The plant is therefore of the pressurized-water type, which employs pressurized light water both as moderator and coolant. The uranium fuel in the core is in the form of uranium dioxide sintered pellets, which are inserted in tubes of stainless steel—which act as cladding and give mechanical strength to the fuel elements. Groups of pins are mounted between end plates to form a complete fuel element. Control of the reactor is performed by inserting or removing boron absorber elements, which replace several of the fuel elements.

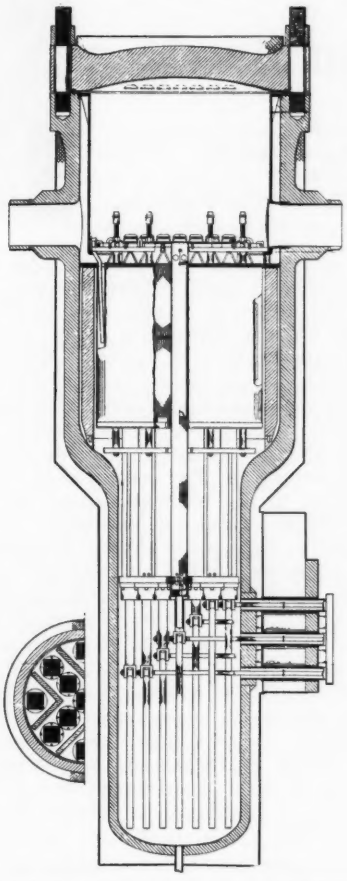
The core is mounted in a pressure vessel capable of withstanding an operating pressure of 2,000 p.s.i.a. and has

La Société Humphreys and Glasgow, qui est associée avec la compagnie américaine ALCO Products, base ses conceptions sur le réacteur A.P.P.R. qui fut construit pour l'armée américaine par ALCO. La même société fournit aussi le A.P.P.R.-1A qui sera construit en Alaska. La puissance thermique des installations civiles offertes par les deux sociétés est de 50 MW et le système convient à la production de l'électricité ou la production de vapeur utilisée pour des usages industriels, ou une combinaison des deux.

Humphreys and Glasgow, die mit der amerikanischen Gesellschaft Alco Products assoziiert sind, basieren ihre Entwürfe auf dem APPR-Reaktor, der für die amerikanische Armee von Alco gebaut wurde. Die gleiche Gesellschaft hat auch die Lieferungen für den APPR-1A, der in Alaska gebaut wird. Die Wärmeerzeugung des zivilen Werks, das die beiden Gesellschaften offerieren, ist 50 MW. Das System ist für die Erzeugung von Elektrizität oder für die Dampferzeugung für chemische Prozesse oder für eine Kombination beider Formen geeignet.

Humphreys and Glasgow que están asociados con la compañía norte-americana Alco Products, basan sus diseños sobre el reactor A.P.P.R. que fué construído para el Ejército de los Estados Unidos por ALCO. La misma compañía está también suministrando el A.P.P.R.-1A que va a ser construído en Alaska. El regimen térmico que las dos compañías están ofreciendo para instalaciones civiles es de 50 MW, y el sistema es conveniente para la generación de electricidad or para la producción de vapor o para una combinación de ambas.

inlet and outlet branches for the circulation of the water. The control rod drive mechanisms penetrate this pressure

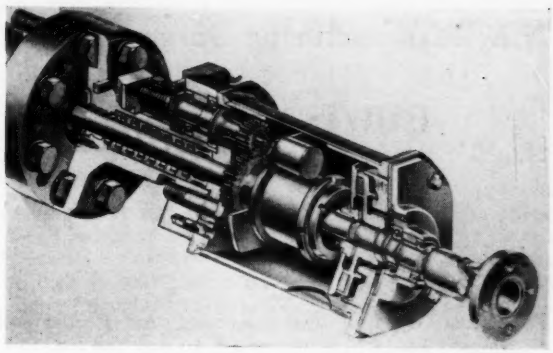


Sectional drawing of reactor pressure vessel.

vessel through a special seal developed by ALCO, and which has given satisfactory service on the APPR. The primary water is circulated through the core around the pipework by a canned rotor circulating pump. From the pressure vessel it enters the tubes of a vertical U-tube heat exchanger, where the heat given to the primary circuit in the core is yielded to the feed water from the secondary circuit on the shell side of the heat exchanger to generate steam at 400 p.s.i.a., dry saturated. This steam may then be employed in a steam turbine or process main as the application requires.

The auxiliary equipment of the primary circuit consists mainly of water-treatment plant, which ensures a high level of purity of this water to reduce the possibility of corrosion of the stainless steel in which the primary circuit is contained and to reduce the activity level of the circuit, and the problems associated with this work have been successfully overcome on the APPR.

The performance of the APPR has been especially noteworthy. Its flexibility under load fluctuation exceeds that of a conventional station of the same output, and variation in electrical load is dependent solely upon the rapidity with which the turbo-alternator plant can accept increase or decrease of load. This most valuable attribute of the plant is achieved by the negative temperature coefficient which, therefore, allows the plant to accept load fluctuations without any manual or instrumental control whatsoever.



Cut-away drawing of ALCO seal for control rod drive.

Control rod movement is only required to adjust for burn-up of the fuel elements.

Safety of the plant is assured by the provision of a vapour container. This consists of a cylindrical steel vessel with hemispherical ends which envelops the whole of the primary circuit. In the most unlikely event of a nuclear incident or rupture of the primary circuit, the vapour container will prevent release of radio-active fission products, it being designed to contain the thermal energy present in both the primary and secondary circuits. This steel vessel is surrounded by a secondary shielding of 3 ft 6 in. of concrete, the primary radiation shield consisting of steel, water and concrete surrounding the reactor pressure vessel.

A vital factor in the economics of the reactor is, of course, the burn-up obtainable from the uranium dioxide fuel in the core. Based on the very considerable development work which has taken place on this type of fuel in the United States, it is reasonable to expect an average burn-up of 10,000 MWd/tonne, and the U.S.A.E.C. have indicated that in certain circumstances they would be prepared to underwrite a guarantee of this figure. The costs per kWh, quoted below, are based on this average burn-up, which will give a core lifetime of two years at 100% load factor or, of course, proportionately longer periods at lower load factors.

That there is a potential market for small nuclear plants is shown by the widespread interest displayed and inquiries have been received from authorities and private concerns in over 20 countries of the world. The power generated from these plants is competitive with that from conventional fuel stations in areas where the scarcity of natural fuel resources gives rise to high transport costs, and with reduction in nuclear costs due to development and larger-scale production, coupled with the trend for increases in conventional fuel costs throughout the world, the area where nuclear power is competitive is ever widening.

It is intended that these plants will be built under substantially fixed-price contracts, and with the above burn-up figure electricity can be produced at an overall cost as low as 1.3 pence/kWh where the load factor is 80% and interest and depreciation is charged at 8%, or 1.6 pence/kWh with capital charges at 15%. For 40% load factor the corresponding figures are 1.9 pence/kWh and 2.5 pence/kWh.

For steam production, which may be for such purposes as process work, space heating or the evaporation of water, the costs are similarly attractive, and while, of course, depending upon the condition required, may be said to be of the order of £0.9 per ton of steam.

N.E. Manufacturing Survey—II

Ruston and Kier

By G. B. R. FEILDEN
M.A., M.I.Mech.E.
(*Engineering Director, Ruston and Hornsby, Ltd., Lincoln*)

IN January 1958, it was announced that **Ruston and Hornsby Ltd.**, of Lincoln, and **J. L. Kier and Co., Ltd.**, of London, had reached an agreement for close technical collaboration in the design of nuclear power stations of 5-25 MW electrical generating capacity. A survey of the possible export market for these power stations was published in *Nuclear Engineering* (November, 1956). This survey revealed that a market exists for the export of these comparatively small power reactors to remote areas where conventional fuel costs are high due to the heavy cost of fuel transport. In such areas, particularly where water supplies are short, there are advantages in using an industrial gas turbine as the prime mover for electricity generation rather than the steam cycles which have hitherto been exclusively used. The success of such a Reactor-Gas Turbine installation depends on the temperature which can be achieved in the reactor, which in turn limits the maximum cycle temperature of the turbine. The development of the High Temperature Gas-Cooled Reactor by the U.K.A.E.A. is therefore being followed very closely. This system will use a number of techniques which are quite familiar to the industrial gas turbine designer.

In addition, the possible applications of nuclear power to industries in which both electricity and process heat are required, are being studied. With a gas-cooled reactor system, this type of application can be met particularly advantageously, owing to the possibility of using a counter-flow type of cooler arrangement, which enables the rejected heat to be taken off at a very much higher temperature than is possible in the case of the condenser cooling water used in steam power plants.

The small nuclear power station for export is a long-term project. It seems possible that high temperature reactors will have been developed to a sufficiently advanced stage to enable them to be offered on commercial terms by 1966. Whilst, at first sight, this may seem to be rather far in the future, it is however not unusual to find generation engineers planning their forward requirements on a similar time scale.

Ruston and Kier are now actively engaged in developing the additional specialized techniques, the full absorption of which is essential before a successful small nuclear power plant can be put into commission. Meanwhile, their productive facilities in traditional fields are being expanded to ensure that they can handle without difficulty the requirements for the construction of complete nuclear power plants either at home or overseas. Work at Lincoln includes the design and production of a 5 MW gas turbine suitable for a nuclear station, and also development work on a number of specialized techniques of essentially nuclear application. Amongst the latter is work on hydrodynamic gas bearings, samples of which have already been successfully tested up to the loadings required for practical designs. A further step is the construction of gas circulators suitable for use in active circuits, where the pumped gas is used as the bearing fluid, so avoiding contamination of the circuit by oil mist. On the civil engineering side, Kier staff stationed at Lincoln are investigating the special requirements for shielding design and construction—and some of the conclusions reached have been at variance with the practice hitherto adopted in this country.

Beginning with the first engineers who went through the Harwell Reactor School Course several years ago, an increasing number of Ruston and Kier personnel have undergone specialized nuclear training, and at the present time staff are on attachment at Establishments of the U.K.A.E.A. With this trained team, as soon as the necessary development work on high temperature reactors has been completed, only a relatively short time will be required to convert experimental and prototype schemes into industrial designs complying with all necessary safety regulations.

The Ruston and Kier organization have for many years been concerned with the erection of Diesel, steam, gas turbine and hydro-electric power stations in all parts of the world, and the fusion of the experience built up in this work places the association in a very strong position for meeting the hitherto unsatisfied demand for power in the rapidly developing regions of the world which are far from sources of fossil fuel or other power supplies—and it is in such locations that the first commercial applications of nuclear power in the medium size range are likely to be made.

La Ruston-Kier est l'association de compagnies de formation la plus récente au Royaume-Uni pour la conception et la construction de centrales d'énergie nucléaire. S'adressant au marché des petits réacteurs, la compagnie s'intéresse particulièrement au développement du réacteur à températures élevées refroidi au gaz, avec le but final de l'incorporation des turbines à gaz dans le système. Des dessins intermédiaires sont aussi à l'étude.

Ruston-Kier ist die allerneuste Gruppe von Gesellschaften, die sich in Gross Britannien zum Entwurf und zum Bau von Atom-Kraftwerken zusammengetan haben. Ihr Ziel ist der Markt der kleinen Reaktoren, und die Gruppe ist besonders interessiert an der Entwickelung des mit hohen Temperaturen arbeitenden gasgekühlten Reaktors, dessen letztes Ziel der Einbau von Gasturbinen direkt im System ist. Dazwischen liegende Entwürfe werden gleichfalls studiert.

La Ruston-Kier es la más reciente asociación de compañías formada en el Reino Unido para el diseño y la construcción de centrales de fuerza nuclear. Con miras al mercado de reactores pequeños, la compañía está particularmente interesada en el desenvolvimiento del reactor de alta temperatura enfriado por gas con la incorporación finalmente de turbinas a gas en el sistema. También se están estudiando diseño intermedios.

N.E. Manufacturing Survey—12

De Havilland Nuclear Power Group

IT has always been the policy of the de Havilland Engine Company to investigate all developments which it is considered may attain a significant place in the field of aircraft propulsion and associated power plant, and this policy resulted in interest being taken in nuclear power developments in 1954. Specialist staff were attached to A.E.R.E. Harwell, to examine the possibility of utilizing this new form of energy for the propulsion of aircraft.

A more significant result of the Company's investigations into small highly-rated systems was the conclusion that high-temperature gas-cooled reactors using ceramic fuel elements could be designed which showed promise of being competitive with conventional prime movers for the production of electrical power outputs in the region of 10-30 MW, and more detailed studies further emphasized their potentially attractive characteristics.

Before an undertaking of this magnitude can be developed, an extensive programme of research must necessarily be carried out. As a practical contribution to this programme the Company has designed and is constructing a high-temperature gas loop in collaboration with, and on behalf of, the A.E.R.E. The loop is to be employed in PLUTO to test a new type of ceramic fuel element.

The PLUTO loop, which is intended to operate with helium cooling, has a secondary cooling system, employing carbon dioxide, capable of providing adequate cooling in the case of a primary coolant failure.

From the experience gained with this equipment it is expected that a significant increase in reactor operating temperatures will be achieved, and this, in turn, should result in higher specific heat outputs and improve thermal efficiency. Furthermore, as primary coolant temperatures as high as 800°C are regarded entirely feasible, it should become possible to give serious consideration to the use of gas turbine plant.

Specialized Components

As an associated aspect of loop construction and in appreciation of the ever-increasing need for specialized components in the nuclear engineering field, the de Havilland Engine Company has developed certain items of equipment as standard commercial products. Typical of these are small high-speed gas circulators incorporating self-acting gas bearings which obviate the need for lubrication and routine maintenance. Experimental investigations are being carried out to determine the behaviour of these bearings under simulated operating conditions, and to provide data on the most suitable materials for their construction.

A variety of small valves is also being developed to meet the exacting requirements specified for radioactive gas circuits. External leakage is minimized by extensive welded and brazed joints, and internal leakage is prevented by careful attention to detail design. Extended rig testing is being performed so that the high standard of reliability demanded for nuclear applications may be achieved.

Le de Havilland Nuclear Power Group a considéré la possibilité de l'emploi de l'énergie nucléaire pour la propulsion des avions. Des études complémentaires ont fait ressortir que le potentiel du H.T.G.C.R. est bien en mesure de faire concurrence aux autres dans la gamme de rendement d'énergie de 10 à 30 MW(E). Pour fournir des données sur ce système la compagnie a construit une boucle de gaz à température élevée en collaboration avec, et pour le compte de l'A.E.R.E. et elle a développé un nombre d'éléments constitutifs tels que des petits circulateurs de gaz à grande vitesse incorporant des paliers à gaz automatiques.

Die de Havilland Nuclear Power Group hat die Möglichkeiten der Ausnutzung der Atomkraft für den Antrieb von Flugzeugen untersucht. Weitere Studien zeigten die Wettbewerbs-Fähigkeit des gasgekühlten Reaktors mit hohen Temperaturen in dem Leistungsbereich von 10–30 MW(E). Um Zahlen für dieses System zu erhalten, hat die Gesellschaft eine Gas-Schleife für hohe Temperaturen in Zusammenarbeit mit der A.E.R.E. und für diese gebaut und hat eine Reihe von Einzelheiten, wie z.B. kleine Gaspumpen für hohe Geschwindigkeiten entwickelt, die selbsttätige Gaslager haben.

El Grupo de Havilland Nuclear Power ha estudiado la posibilidad de emplear propulsión nuclear para aviones. Estudios adicionales hechos indican la potencial competidora de la H.T.G.C.R. en la gama de producción de potencia de 10–30 MW (E). Para proveer datos sobre este sistema, la compañía ha construido en lazo de gas de alta temperatura en colaboración con, y por cuenta de, la A.E.R.E., y ha evolucionado varios componentes, tales como pequeños circuladores de gas a alta velocidad, incorporando soportes a gas autoactuantes.

Head Wrightson Processes Ltd.

Ce fut la Head Wrightson Processes la compagnie choisie comme l'entrepreneur principal pour l'A.E.A. pour les réacteurs d'études DIDO, PLUTO, et DMTR. La compagnie est aussi en train de construire des réacteurs analogues en Australie en Allemagne et au Danemark. Des différences minimes existent dans les dessins de ces réacteurs, particulièrement à l'égard des facilités expérimentales prévues, mais un haut degré de standardisation a été appliqué et ce type de réacteur d'essais de matériaux attire en une mesure considérable l'attention d'un grand nombre de pays du monde entier.

Head Wrightson Processes sind von der A.E.A. als die Haupt-Bauunternehmer für die Forschungsreaktoren DIDO, PLUTO und DMTR ausersehen. Die Gesellschaft hat ferner ähnliche Reaktoren in Australien, Deutschland und Dänemark im Bau. Es sind zwar kleinere Unterschiede in den Entwürfen zu diesen Reaktoren, insbesondere in den Anlagen für experimentelle Untersuchungen, es ist aber von Standardisierung in grossem Masse Gebrauch gemacht worden, und diese Art von Reaktoren zur Material-Prüfung hat in vielen Ländern über die ganze Welt beträchtliches Interesse gefunden.

Head Wrightson Processes fueron nombrados los principales contratistas de la A.E.A. para los reactores de investigación DIDO, PLUTO y DMTR. La Compañía también está construyendo reactores similares en Australia, Alemania y Dinamarca. Existen diferencias pequeñas en los diseños de estos reactores, notablemente en las facilidades experimentales provistas, pero se ha aplicada una gran medida de estandardización y este tipo de reactor para ensayar materiales está recibiendo considerable atención en muchos paises en todas partes del mundo.

Reactors in the U.K.

POWER AND PLUTONIUM REACTORS

Location	Owner	Designer	No. of reactors	Reactor rating (H)	Station output (E)	Status	N.E. ref.
Windscale ..	U.K.A.E.A.	U.K.A.E.A.	2	Unpublished	—	No. 1, commissioned 1950; U fire Oct., '57; abandoned. No. 2, commissioned 1951; closed down Oct., '57; future undetermined.	June, '56, p. 132. Dec., '57, p. 510.
Calder Hall ..	U.K.A.E.A.	U.K.A.E.A.	4	200 MW	150 MW	No. 1, diverged May, 1956. No. 2, diverged Nov., 1956. No. 3, diverged March, 1958. No. 4, divergence imminent.	†Oct., '56. Dec., '56.
Chapelcross ..	U.K.A.E.A.	U.K.A.E.A.	4	200 MW	150 MW	Ground broken Aug., 1955. Reactors scheduled to diverge in succession during 1959.	(As Calder Hall)
Berkeley ..	C.E.G.B.	A.E.I.–J.T.	2	550 MW	275 MW	Ground broken Jan., 1957. Operation scheduled 1960.	†March, '57.
Bradwell ..	C.E.G.B.	N.P.P.C.	2	530 MW	300 MW	Ground broken Jan., 1957. Operation scheduled 1960.	†April, '57.
Hinkley Point ..	C.E.G.B.	E.E.–B. & W. –T.W.	2	980 MW	300 MW	Ground broken Oct., 1957. Operation scheduled 1961/62.	Oct., '57, p. 423. †July, '58.
Hunterston ..	S.S.E.B.	G.E.C., S.-C.	2	535 MW	500 MW	Ground broken Oct., 1957. Operation scheduled 1961/62.	†Feb., '57.

MATERIALS TESTING REACTORS

Name	Location	Type	Rating	Peak flux	Start-up	Purpose	N.E. ref.
DIDO	A.E.R.E.	Heavy water	10 MW	10^{14}n/cm², sec	1956	Isotope prod., neutron physics, materials irrad.	Dec., '56, p. 391; †Jan., '57.
PLUTO ..	A.E.R.E.	Heavy water	10 MW	10^{14}	1957	Materials testing; large loop work.	Dec., '57, p. 513; †April, '58.
DMTR	Dounreay	Heavy water	10 MW	10^{14}	1958	Identical to PLUTO.	July '57, p. 286.

RESEARCH AND EXPERIMENTAL REACTORS

Name	Location	Moderator	Coolant	Fuel	Peak flux	Rating	Start-up	Purpose	N.E. ref.
GLEEP	A.E.R.E.	Graphite	Air	Nat. U metal & UO_2	$3.7.10^{10}$ n/cm², sec	100 kW	1947	Graphite testing; oscillator expts.; biological irrad.	May, '56, p. 72.
BEPO	A.E.R.E.	Graphite	Air	Nat. U	2.10^{12}	6 MW	1948	Isotope prod.; gen. irrad.	†April, '56. May, '56, p. 74.
ZEPHYR	A.E.R.E.	—	—	Pu	8.10^{8} (f)	few W	1954	Fast reactor studies.	April, '56, p. 9.
DIMPLE	A.E.R.E.	D_2O	—	Varies	$\sim10^{8}$	100 W	1954	Thermal reactor studies.	April, '56, p. 8; †Aug., '56.
LIDO	A.E.R.E.	H_2O	H_2O	U^{235}	10^{12}	100 kW	1956	Reactor and shielding studies.	June, '57, p. 245. †Nov., '57.
NERO	A.E.R.E.	Graphite	—	Slightly enrich. U	$\sim10^{8}$	$<$100 W	1957	Research for A.G.R.	—
NEPTUNE	A.E.R.E.	H_2O	—	Enrich. U	$\sim10^{8}$	$<$100 W	1957	Marine propulsion studies.	Aug., '58, p. 319.
HAZEL	A.E.R.E.	D_2O	—	Uranyl fluoride	$\sim10^{6}$	$<$1 W	1958	Basic HAR research.	—
DFR	Dounreay	—	Na/K	U^{235}	—	60 MW	1959*	Fast reactor expt.	†June, '57.
MERLIN	A.E.I. Labs., Aldermaston	H_2O	H_2O	U^{235}	2.10^{14} (epith.) 5.10^{13} (th.)	5 MW	1958*	First U.K. private research reactor.	Jan., '57, p. 10; Feb., '57 p. 66; †May, '58.
HERALD	A.W.R.E.	H_2O	H_2O	U^{235}	10^{14}	5 MW	1958*	General research.	(As MERLIN)
HORACE	A.W.R.E.	H_2O	—	U^{235}	Small	$<$25 W	1958	Core design for HERALD.	—
H.T.G.C.	Winfrith Heath	Graphite	Gas	U^{235}			1959*	Advanced gas-cooled reactor prototype.	—
A.G.R.	Windscale (prob.)	Graphite	CO_2	Slightly enrich. U			1961*	High-temp. gas-cooled expt.	—

* Not yet commissioned. † Two-page pull-out drawing.

THE GENEVA PROGRAMME

In addition to the General Sessions, the Conference papers are divided up into five sections.

Series A Theoretical physics.
Series B Reactors and reactor physics.
Series C Chemistry.
Series D Isotopes.
Series E Materials.

General Sessions

See Table 1.

Series A and B

See Table 2.

Series C, D, E

See Table 3.

Evening Lectures Open to the Public

U.N.O. has announced a series of six lectures to be given on three evenings by leading scientists from the U.K., the U.S., India and Russia.

Friday, September 5

"The rôle of nuclear power in the under-developed countries," by Dr. Homi Bhabha.

"Recent developments in fundamental physics," by Prof. Igor E. Tamm.

Wednesday, September 10

"Recent developments in the transplutonic elements," by Dr. Glenn T. Seaborg.

"Implications of atomic energy in the field of biology," by Prof. Vladimir A. Engelhardt.

Friday, September 12

"International collaboration in science," by Dr. Lloyd V. Berkner.

"Trends in the development of the peaceful use of the atom" (Conference Survey), by Sir John Cockcroft.

TABLE 1 General Sessions

Date		Session Number and Subject
Sept. 1, Monday	a.m.	1. Opening of the Conference
	p.m.	2. The Future of Nuclear Power
Sept. 2, Tuesday	a.m.	3. Experience with Nuclear Power Plants
	p.m.	4. Possibility of Controlled Fusion
Sept. 3, Wednesday	a.m.	5a. Operational Experience in Health and Safety 5b. Progress in the Use of Isotopes
	p.m.	6. Use of Nuclear Energy for Purposes Other Than Generation of Electricity
Sept. 4, Thursday	a.m.	7. Plans for Construction of Nuclear Power Plants
Sept. 9, Tuesday	a.m.	15. Recent Developments in Fundamental Physics
Sept. 13, Saturday	a.m.	23a. Supply and Training of Technical Personnel 23b. Recent Developments in International Collaboration 23c. Closing of the Conference

TABLE 2 Series A and B

Date		Session Number and Subject	
		Series A	Series B
Sept. 3, Wednesday	a.m.	A–5. Theoretical Aspects of Plasma Physics	B–5. Research and Engineering Test Reactors
	p.m.	A–6. Experimental Aspects of Plasma Physics	—
Sept. 4, Thursday	a.m.	A–7. Controlled Fusion Devices, Part I	—
	p.m.	A–8. FREE	B–8. FREE
Sept. 5, Friday	a.m.	A–9. Controlled Fusion Devices, Part II	B–9. Power Reactors
	p.m.	A–10. Special Topics and Instrumentation in Fusion	B–10. Experimental Power Reactors
Sept. 6, Saturday	a.m.	A–11. Nuclear Data	B–11. Experience with Reactors, Part I
	p.m.	A–12. Nuclear Data and Reactor Theory	B–12. Experience with Reactors, Part II
Sept. 8, Monday	a.m.	A–13. Reactor Theory and Computing Methods	B–13. Safety, Location and Containment
	p.m.	A–14. Reactor Kinetics and Control	B–14. Economics of Nuclear Power
Sept. 9, Tuesday	a.m.	—	B–15. Fuel Cycles
	p.m.	A–16. FREE	B–16. FREE
Sept. 10, Wednesday	a.m.	A–17. Physics of Elementary Particles	B–17. Reactor Physics, Part I
	p.m.	A–18. Nuclear Instrumentation and Techniques	B–18. Reactor Physics, Part II
Sept. 11, Thursday	a.m.	A–19. Basic Physics in Nuclear Energy Part I	B–19. Reactor Physics, Part III
	p.m.	A–20. FREE	B–20. FREE
Sept. 12, Friday	a.m.	A–21. Basic Physics in Nuclear Energy, Part II	B–21. Reactor Physics, Part IV
	p.m.	A–22. Basic Physics in Nuclear Energy, Part III	B–22. FREE

TABLE 3 Series C, D, E

Date		Session Number and Subject		
		Series C	Series D	Series E
Sept. 3, Wednesday	a.m.	—	—	E–5. Raw Material and Supplies
	p.m.	—	D–6. Isotope Production and Use in Research	E–6. Ore Treatment, Part I
Sept. 4, Thursday	a.m.	—	D–7. Use of Isotopes in Industry	E–7a. Ore Treatment, Part II E–7b. Geochemistry
	p.m.	C–8. FREE	D–8. FREE	E–8. FREE
Sept. 5, Friday	a.m.	C–9. Basic Chemistry in Nuclear Energy, Part I	D–9. Use of Isotopes in Biochemistry and Physiology, Part I	E–9. Mineralogy, Geology and Prospecting
	p.m.	C–10. Basic Chemistry in Nuclear Energy, Part II	D–10. Use of Isotopes in Biochemistry and Physiology, Part II	E–10. Mining Aspects and Instrumentation
Sept. 6, Saturday	a.m.	C–11. Basic Chemistry in Nuclear Energy, Part III	D–11. Use of Isotopes in Medicine, Part I	E–11. Production of Nuclear Materials, Part I
	p.m.	C–12. Chemical Effects of Radiation, Part I	D–12. Use of Isotopes in Medicine, Part II	E–12. Production of Nuclear Materials, Part II
Sept. 8, Monday	a.m.	C–13. Chemical Effects of Radiation, Part II	D–13. Dosimetry and Standards	E–13. Basic Studies in Metallurgy and Ceramics
	p.m.	C–14. Methods of Separation of Isotopes, Part I	D–14. Biological Effects of Radiation, Part I	E–14. Properties of Reactor Materials, Part I
Sept. 9, Tuesday	a.m.	C–15. Methods of Separation of Isotopes, Part II	D–15. Biological Effects of Radiation, Part II	E–15. Properties of Reactor Materials, Part II
	p.m.	C–16. FREE	D–16. FREE	E–16. FREE
Sept. 10, Wednesday	a.m.	C–17. Processing of Irradiated Fuels, Part I	D–17. Experience in Radiological Protection, Part I	E–17. Properties of Reactor Materials, Part III
	p.m.	C–18. Processing of Irradiated Fuels, Part II	D–18. Experience in Radiological Protection, Part II	E–18. Properties of Reactor Materials, Part IV
Sept. 11, Thursday	a.m.	C–19. Handling of Radioactive Materials	D–19. Environmental Aspects of Large Scale Use of Atomic Energy	E–19. Fabrication of Fuels
	p.m.	C–20. FREE	D–20. FREE	E–20. FREE
Sept. 12, Friday	a.m.	C–21. Treatment of Radioactive Wastes, Part I	D–21. Use of Isotopes in Agriculture, Part I	E–21. Reactor Technology, Part I
	p.m.	C–22. Treatment of Radioactive Wastes, Part II	D–22. Use of Isotopes in Agriculture, Part II	E–22. Reactor Technology, Part II

U.K. Papers at Geneva

1.—**Hydromagnetic Disturbances of Large Amplitude in a Plasma,** by J. H. Adlam, J. E. Allen (A.E.R.E.).

2.—**Theoretical Problems Associated with Zeta,** by W. B. Thompson, J. Hubbard, W. Marshall, S. J. Roberts, R. J. Taylor (A.E.R.E.), S. F. Edwards (Univ. of Birmingham).

3.—**A Review of Controlled Thermonuclear Research at the A.E.I. Research Laboratory,** by T. E. Allibone, D. R. Chick, A. A. Ware (A.E.I., Aldermaston); Sir George Thomson (Univ. of Cambridge).

6.—**Fission Processes in the Proton Bombardment of Th232, U238 and Pu239,** by J. P. Butler (A.E.R.E.); B. J. Bowles, F. Brown.

10.—**Measurements of Reactor Spectra by Time-of-Flight and Integral Methods,** by C. G. Campbell (A.E.R.E.); M. S. Coates, R. G. Freemantle, M. J. Poole.

14.—**The Use of the Pile Oscillator in Thermal Reactor Problems,** by H. Rose (A.E.R.E.); W. A. Cooper, R. B. Tattersall.

15.—**General Review of Graphite-moderated Thermal Reactor Calculations,** by C. G. Campbell, P. W. Mummery (A.E.R.E.); B. Cutts, I. A. Mossop (U.K.A.E.A.G.).

18.—**The Calculation of Thermal Neutron Spectra,** by A. Hassitt (A.E.R.E.); P. Schofield, J. H. Tait.

21.—**The Derivation of Reactor Heat Transfer Transient Equations for Gas-cooled Graphite-moderated Thermal Reactors,** by T. J. O'Neill (G.E.C.).

22.—**Research Reactor Utilisation,** by F. W. Fenning, F. R. Jackson (A.E.R.E.); K. Q. Bagley, (U.K.A.E.A.I.G.).

26.—**The Actinide Oxides,** by L. E. J. Roberts (A.E.R.E.).

32.—**Processing of Reactor Fuels by Liquid Metals,** by I. L. Jenkins (A.E.R.E.); N. J. Keen, F. S. Martin.

33.—**The Stability of a Constricted Gas Discharge,** by R. J. Taylor (A.E.R.E.).

39.—**Experimental Work with Zero Energy Fast Reactors,** by R. D. Smith (A.E.R.E.); J. E. Sanders.

40.—**Critical and Sub-critical Assembly Experiments with a Two-group Correlation of Results,** by C. G. Campbell (A.E.R.E.); I. S. Grant.

41.—**The Alpha-ray Activity of Humans and their Environment,** by W. V. Mayneord (Inst. of Cancer Research); J. M. Radley, R. C. Turner.

43.—**Air-borne Radiometric Survey of Cornwall,** by S. H. U. Bowie, J. M. Miller (Geo. Survey of Gt. Britain); J. Pickup, D. Williams (A.E.R.E.).

44.—**The Manufacture of Fuel Elements for the Dounreay Fast Reactor,** by C. J. Turner (U.K.A.E.A.I.G.); L. R. Williams.

46.—**Some Chemical Problems of Homogeneous Aqueous Reactors,** by J. K. Dawson (A.E.R.E.); B. Cox, R. Murdoch, R. G. Sowden.

48.—**The Polyzonal Spiral Fuel Element,** by H. L. Ritz (N.P.P.C.).

50.—**Fuel Element Behaviour under Irradiation,** by V. W. Eldred (U.K.A.E.A.I.G.); G. B. Greenough, P. Leech.

51.—**The Effects of Fast-electron and Pile Irradiation in Polyphenyls at High Temperatures,** by W. G. Burns (A.E.R.E.); T. F. Williams, W. Wild.

53.—**Analytical Methods for Evaluating Flux Distribution in Small Power Producing Reactors,** by A. Jeffrey (Rolls-Royce).

54.—**The Economics of Enrichment and of the Use of Plutonium and Uranium-233,** by N. J. Franklin, J. M. Hill, J. C. C. Stewart (U.K.A.E.A.I.G.); C. A Rennie (A.E.R.E.).

58.—**Experience in the Design of Irradiation Loops,** by H. Cartwright, B. E. Eltham (U.K.A.E.A.I.G.); R. F. Jackson (A.E.R.E.).

59.—**The Design and Operation of a High Intensity Pulsed Neutron Source Using a Booster Target,** by G. D. James (A.E.R.E.); M. J. Poole, R. J. Royston, J. H. Tait, C. A. Uttley, E. R. Wiblin.

61.—**Dosimetry Aspects of the Production of Bone Tumours by Radiation,** by L. F. Lamerton (Inst. of Cancer Research).

65.—**Recent Research in Chemical Applications of Large Radiation Sources,** by R. Roberts (A.E.R.E.); F. Dalton, P. Hayden, P. R. Hills.

67.—**Principles Underlying the Therapeutic Use of Mega-voltage Radiation,** by E. Ralston Paterson (Christie Hosp. and Holt Radium Inst.).

68.—**Pituitary Irradiation,** by F. Ellis (Churchill Hosp.).

71.—**The Physical Metallurgy of Plutonium,** by M. B. Waldron (A.E.R.E.); J. Garstone, J. A. Lee, P. G. Mardon, J. A. C. Marples, D. M. Poole, G. K. Williamson.

72.—**Economics of Nuclear Power,** by J. A. Jukes (U.K.A.E.A., L.O.).

73.—**Current Re-designs of Calder Hall,** by J. B. W. Cunningham (U.K.A.E.A.I.G.).

76.—**The Possibility of the Direct Application of Fission Fragment Energy to Chemical Processes,** by J. K. Dawson (A.E.R.E.); G. Long, F. Moseley, R. G. Sowden.

77.—**Biological Studies with Labelled Amino Acids and Proteins,** by A. S. McFarlane (Nat. Inst. for Med. Res.).

78.—**Controlled Thermonuclear Research in the United Kingdom,** by P. C. Thonemann (A.E.R.E.).

79.—**Recent Developments in Analysis with Special Reference to Reactor Research,** by H. M. Davis, F. W. J. Garton, H. I. Shalgosky, E. N. Jenkins, G. W. C. Milner (A.E.R.E.).

80.—**The Mechanical Properties, Embrittlement and Metallurgical Stability of Irradiated Metals and Alloys,** by M. J. Makin, D. R. Harries, R. E. Smallman (A.E.R.E.); A. T. Churchman (A.E.I.).

81.—**Swelling and Inert Gas Diffusion in Irradiated Uranium,** by R. S. Barnes, A. J. E. Foreman, O. S. Pall, S. F. Pugh, G. N. Walton (A.E.R.E.); A. T. Churchman (A.E.I.); G. C. Curtis, V. W. Eldred, J. A. Enderby, L. M. Wyatt (U.K.A.E.A.I.G.).

82.—**Chemical Processes at U.K. Atomic Energy Authority Works, Dounreay,** by G. R. Howells (U.K.A.E.A.I.G.); J. S. Broadley, C. Buck, K. Hartley, T. A. Parry, B. F. Warner, J. A. Williams.

88.—**Critical Assembly Experiments at Dounreay,** by G. W. K. Ford (U.K.A.E.A.I.G.); B. J. Owen, J. G. Walford.

94.—**The Application of Radio-tracers to the Measurements of Engine Wear in Moving Vehicles,** by J. H. Deterding (Shell Res.); J. R. B. Calow.

97.—**Spontaneous and Induced Changes in Cell-populations in Heavily Irradiated Mice,** by D. W. H. Barnes (M.R.C.); C. E. Ford, J. F. Loutit.

98.—**Chromosomes and Carcinogenesis: Observations on Radiation-induced Leukaemias,** by C. E. Ford (M.R.C.); R. H. Mole.

99.—**Occupational Hazards from Exposure to Ionizing Radiations: A Study of the Causes of Death and the Mortality Rate Among British Radiologists,** by W. M. Court Brown (M.R.C.); Richard Doll.

102.—**The Production of Boron-10 and Other Stable Isotopes,** by A. O. Edmunds (20th Century Electronics); F. C. Loveless.

262.—**The U.K. Programme for the Development of Nuclear Power,** by W. Strath (U.K.A.E.A.).

267.—**Safety Aspects of the Calder Hall-type Reactor in Theory and Experiment,** by G. Brown, H. Kronberger, F. M. Leslie, J. Moore (U.K.A.E.A.I.G.); P. W. Mummery (A.E.R.E.).

268.—**Contributions to Knowledge of Elementary Particles by Experiments with Cosmic Radiation,** by C F. Powell (Univ. of Bristol).

269.—**Education and Training in Reactor Technology and Radioisotope Techniques in the U.K.,** by H. Cartwright, K. Frost (U.K.A.E.A.I.G.); J. Diamond (Univ. of Manchester); R. A. Faires, D. J. Littler (A.E.R.E.); J. M. Kay, W. Murgatroyd (Univ. of London); J. Walker (Univ. of Birmingham); D. F. Welch (A.E.I.-J.T.).

270.—**Liquid Metal Fuel Technology,** by B. R. T. Frost (A.E.R.E.).

271.—**Synthetic Inorganic Ion Exchangers and their Applications in Atomic Energy,** by C. B. Amphlett (A.E.R.E.); J. M. Hutcheon.

273.—**Steam Cycles for Gas-cooled Reactors,** by W. R. Wootton (Babcock and Wilcox); A. J. Taylor, N. G. Worley.

274.—**The Dounreay Fast Reactor—Basic Problems in Design,** by H. Cartwright (U.K.A.E.A.I.G.), J. Tatlock.

277.—**Applications of I132 to Measurements of Day-to-day Changes in the Human Thyroid,** by K. E. Halnan (M.R.C.); E. E. Pochin.

278.—**The Preparation and Use of Oxygen-15 with Particular Reference to its Value in the Study of Pulmonary Malfunction,** by N. A. Dyson, G. R. Newbery (M.R.C.); P. Hugh-Jones, J. B. West.

280.—**The Metabolism of Hexoestrol by Ruminants,** by R. F. Glascock (Nat. Inst. for Res. in Dairying); W. G. Hoekstra.

284.—**Radiation Labelling of Organic Compounds with Carbon-14,** by C. N. Turton (A.E.R.E.).

285.—**Application of Fluorescent X-ray Production by Electron Capture Isotopes,** by G. B. Cook (A.E.R.E.); C. E. Mellish, J. A. Payne.

287.—**The Availability to Plants of Divalent Cations in the Soil,** by R. Scott Russell (Ag. Res. Council); P. Newbould, R. K. Schofield (Univ. of Oxford).

295.—**Radiological Protection at the Springfield Works of the U.K. Atomic Energy Authority,** by A. Butterworth (U.K.A.E.A.I.G.), A. Cook, H. Mason.

297.—**The Disposal of Radioactive Liquid Wastes into Coastal Waters,** by H. J. Dunster (U.K.A.E.A. I.G.).

299.—**Recent Developments in Instrumentation for the Survey, Assay and Mining of Radioactive Raw Materials,** by H. Bisby (A.E.R.E.); D. Williams.

300.—**The Reduction of Uranium Hexafluoride by Carbon Tetrachloride,** by D. A. Collins (U.K.A.E.A.I.G.); J. S. Nairn, J. C. Taylor.

301.—**Experience in the U.K. Atomic Energy Industry 1947-58,** by Sir Leonard Owen (U.K.A.E.A. I.G.).

302.—**Control of Radiation Exposure in the U.K. Atomic Industry,** by H. J. Dunster, F. R. Farmer, A. S. McLean (U.K.A.E.A.I.G.); W. G. Marley (A.E.R.E.).

303.—**Chemical Studies of Carbon Dioxide and Graphite under Reactor Conditions,** by A. R. Anderson (A.E.R.E.); H. W. Davidson (G.E.C.); R. Lind, C. Tyzack (U.K.A.E.A.I.G.); D. R. Stranks (Univ. of Leeds).

304.—**The Chemistry and Metallurgy of Neptunium,** by H. A. C. McKay, M. B. Waldron (A.E.R.E.); J. S. Nairn (U.K.A.E.A.I.G.).

307.—**The Chemical Processing of Irradiated Fuels from Thermal Reactors,** by G. R. Howells (U.K.A.E.A.I.G.); T. G. Hughes, D. R. Mackey, K. Saddington.

308.—**Development of a Self-contained Scheme for the Treatment of Low Activity Waste,** by R. H. Burns (A.E.R.E.); E. Glueckauf.

309.—**The Recovery of Radio Krypton from Dissolver Waste Gases by Fractional Extraction in Solvents,** by R. W. McIlroy (A.E.R.E.); E. Glueckauf, H. J. de Nordwall, F. C. W. Pummery.

312.—**Advances in the Design of Gas-cooled Power Reactors,** by R. V. Moore (U.K.A.E.A.I.G.); L. Grainger, H. Kronberger.

313.—**The Merlin Research Reactor,** by T. E. Allibone (A.E.I., Aldermaston); D. R. Chick, K. Firth, B. Millar, I. Munro, A. J. Salmon.

314.—**The Possibilities of Achieving High Temperatures in a Gas-cooled Reactor,** by L. R. Shepherd (A.E.R.E.).

316.—**District Surveys Following the Windscale Incident,** by A. S. McLean (U.K.A.E.A.I.G.); H. J. Dunster, H. Howells, W. L. Templeton.

319.—**Fabrication Technology of Beryllia and Beryllium,** by D. T. Livey (A.E.R.E.); J. Williams.

1446.—**Economic Aspects of the U.K. Nuclear Power Programme,** by J. C. Duckworth (C.E.G.B.); E. H. Jones.

1453.—**Developments in the Analytical Service Given to Industrial Atomic Energy,** by F. Woodman (U.K.A.E.A.I.G.); T. G. Clinton, W. Fletcher, G. A. Welch.

1458.—**The Extraction of Actinide Elements from Wastes,** by J. S. Nairn, D. A. Collins (U.K.A.E.A. I.G.); H. A. C. McKay (A.E.R.E.); A. G. Maddock (Univ. of Cambridge).

1459.—**The Design, Construction and Equipment of Some High-activity Cells in the U.K.,** by J. E. Bown (A.E.R.E.); E. D. Ryam (U.K.A.E.A.I.G.).

1460.—**Studies of High Current Gas Dischargers at High Rates of Build-up,** by S. C. Curran (A.W.R.E.); K. W. Allen, H. A. B. Bodin, R. A. Fitch, N. J. Peacock, J. A. Reynolds.

1462.—**Stability Considerations in the Design of Fast Reactors,** by R. T. Ackroyd, J. E. Mann, J. D. McCullen (U.K.A.E.A.I.G.); G. H. Kinchin (A.E.R.E.).

1467.—**Body Radioactivity Measurement as an Aid in Assessing Contamination by Radio-Nuclides,** by J. Rundo (A.E.R.E.).

1468.—**Thorium Metal Production by a Chlorination Process,** by A. R. Gibson (A.E.R.E.); J. H. Buddery, J. R. Chalkley, R. P. Marshall.

1516.—**Chemical Changes Induced in Organic Systems by Ionizing Radiations,** by F. S. Dainton (Univ. of Leeds); N. Miller, W. H. Stafford (Univ. of Edinburgh); G. A. Swan (Univ. of Durham).

1517.—**Primary Products in the Irradiation of Aqueous Solutions,** by J. H. Baxendale (Univ. of Manchester); F. S. Dainton (Univ. of Leeds); N. Miller (Univ. of Edinburgh); J. Weiss (Univ. of Durham).

1519.—**The Design and Performance of Zeta,** by P. C. Thonemann, R. Carruthers, J. T. D. Mitchell, R. S. Pease (A.E.R.E.); J. Blears, E. R. Hartill (Metropolitan-Vickers).

1520.—**Diagnostic Techniques in Controlled Thermonuclear Research,** by G. N. Harding (A.E.R.E.); A. N. Dellis, A. Gibson, B. Jones, D. J. Lees, R. W. P. McWhirter, S. A. Ramsden, S. Ward.

1521.—**High Energy Machine Physics in Britain,** by H. W. B. Skinner (Univ. of Liverpool).

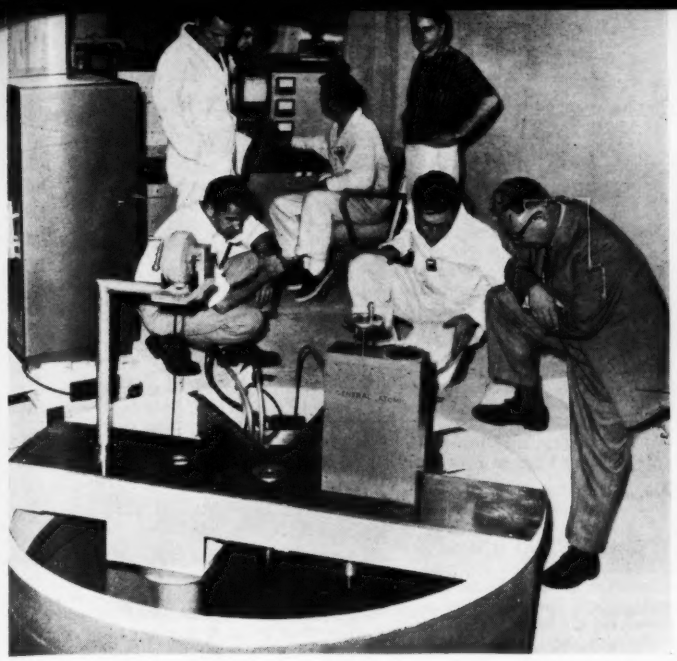
1522.—**Operating Experience at Calder Hall,** by H. G. Davey (U.K.A.E.A.I.G.); J. Gawthrop, T. N. Marsham.

1524.—**The Safety of the Design and Use of the DIDO Class of Research Reactors,** by R. F. Jackson (A.E.R.E.); F. W. Fenning, B. S. Smith.

1805.—**The Release of Wigner Energy in the Harwell Reactor, BEPO,** by R. F. Jackson (A.E.R.E.).

2331.—**Safety and Siting Considerations for Gas-cooled Thermal Reactors of the Calder Hall type,** by F. R. Farmer, P. T. Fletcher (U.K.A.E.A.I.G.); T. M. Fry (A.E.R.E.).

2496.—**The Medical Value of the Localization of Radioactive Isotopes,** by E. E. Pochin (M.R.C.).



One of the two reactors which will be operating at Geneva for the duration of the "Atoms for Peace" Conference is the TRIGA—a multi-purpose research reactor of 10 to 30 kW power. TRIGA has been developed and built by General Atomic Division of General Dynamics Corporation.

World News

International

TRANS-POLAR VOYAGE of the *U.S.S. Nautilus* marks the boldest venture yet in the series of practical demonstrations of the superiority of submarines powered by nuclear reactors over conventional units. When taking part in N.A.T.O. exercises last September *Nautilus* steamed 5,007 miles submerged at an average speed of 15 knots. On the North Pole route, *Nautilus* left from Pearl Harbour on July 22, passed through the Bering Straits between Siberia and Alaska, steamed under the North Pole at 03.15 GMT on Monday, August 4, and arrived in Portland harbour, Dorset, on Tuesday, August 12. The voyage involved a journey of 8,146 miles at an average speed of 17 knots. As recorded on page 403 of this issue the captain of the *Nautilus*, Commander W. Anderson, was presented with the Legion of Merit by President Eisenhower to commemorate this feat of seamanship. Commander Anderson was taken off his vessel and flown to Washington for the presentation on August 8. On arrival in Portland, the *Nautilus* received a great ovation from a large crowd of well-wishers. On behalf of President Eisenhower, the American Ambassador presented the whole crew with a presidential citation. Shortly after the epic voyage it was announced that a second U.S. nuclear submarine, *U.S.S. Skate*, had also completed a trans-polar voyage successfully. The *Seawolf*, the third U.S. nuclear submarine, has been conducting prolonged underwater Atlantic trials for atmospheric and environmental control tests.

Sea Dragon, the sixth U.S. nuclear submarine to be authorized, was launched on August 16; *Triton*, the eighth, was launched at Groton, Connecticut, on August 19. Displacing 5,450 tons, *Triton* has two PW reactors. The vessel will cost more than £35 million.

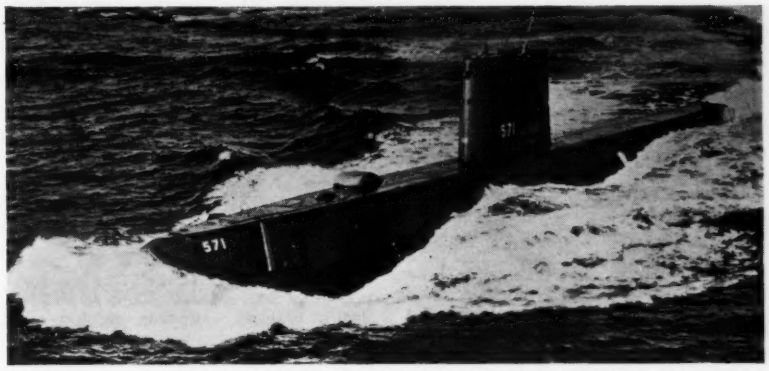
AGREEMENT for exchange of information on fast breeder reactors between the U.K.A.E.A. and the Power Reactor Development Co. of Detroit, U.S.A. was concluded on August 8. P.R.D.C. are constructing the Enrico Fermi I power plant, a fast reactor at Lagoona Beach, Monroe, Michigan. The reactor is scheduled for operation in late 1960, a year to eighteen months after Dounreay goes critical. The agreement comes into force on October 1 and will continue for five years.

ANGLO-AMERICAN agreement for extended co-operation in nuclear energy was brought into effect on August 4. The agreement had lain before Congress for 30 days without objection. Under its terms the British government are authorized to purchase a propulsion unit and fuel for a nuclear submarine and, at the same time are given access to information on nuclear weapons.

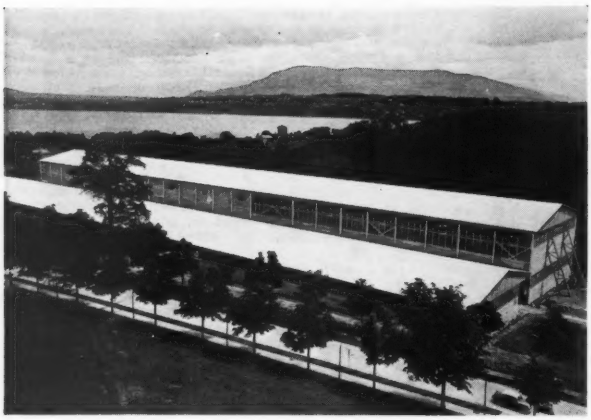
REACTORS AT GENEVA. Two U.S. reactors can be seen in operation during the "Atoms for Peace" conference and exhibitions in Geneva from September 1 to 14. General Atomic's TRIGA is installed in the U.N. exhibition hall. TRIGA, an entirely new concept of homogeneous reactor with a steady-state operating range of 10 to 30 kW, is powered by uranium-zirconium hydride fuel elements. During the conference the reactor will provide short-lived radioisotopes for the U.S. Life Sciences exhibit. The second U.S. reactor, a 10-kW ARGONAUT, will be assembled, tested and put into operation during the conference by a team of engineers from Argonne National Laboratory.

SIX SCIENTISTS will present a series of evening lectures in Geneva during the conference. The lectures, which will be open to the public, will be given on three evenings. Speakers comprise Dr. Homi Bhabha, chairman, Indian A.E.C.; Vladimir A. Engelhardt and Igor E. Tamm, U.S.S.R.; Sir John Cockcroft; Dr. Lloyd V. Berkner and Dr. Glenn T. Seaborg of the U.S.

SCIENTIFIC INFORMATION was the subject to two recent agreements for collaboration signed by I.A.E.A. Under the first I.A.E.A. and UNESCO contribute equally to the publication of an eight-language international electro-technical vocabulary and under the second close liaison has been established between the I.A.E.A. library and the central library of the Institutes of Physics of Vienna University.



U.S.S. Nautilus, the world's first nuclear-powered submarine, made history early in August by becoming the first vessel to complete a trans-polar crossing at the North Pole.



The United Nations Scientific Exhibition at Geneva is housed in this building erected in the grounds of the Palais des Nations. In an area of approximately 90,000 sq. ft some twenty-one governments are featuring work done in their respective countries.

United Kingdom

CONSENT for construction of a 500 MW nuclear power station at Trawsfynydd, N. Wales has been given by the Minister of Power. He has also agreed to the erection of 275 kV transmission lines connecting the station to the proposed pumped storage scheme and to Connah's Quay power station.

MODIFICATIONS TO ZETA were outlined by a Mr. E. R. Harthill of Met.-Vick's transformer department at the company's recent summer school. The modifications will give a current of approximately 1 million A for up to 0.3 seconds—five times the current of the earlier experiments for up to 100 times duration. A ten-fold increase in the associated capacitor bank will result in a storage capacity of five megajoules. Half will be pulsed into ZETA, the remainder will be discharged more steadily to help maintain the current flow within the torus. The modified torus will have a stainless steel inner tube with water cooling.

N. SCOTLAND H.E. BOARD is interested in nuclear power production although no early move is expected. At present existing plant is sufficient for the area's needs. In conjunction with the South of Scotland E.B. the Board is developing pumped storage plant: a dual purpose turbine-pump was recently operated at East Kilbride.

COMPLETION of the fast breeder reactor at Dounreay is scheduled for the end of this year according to a recent written Parliamentary reply. It is likely that the reactor will go critical in the late spring of 1959. Development of the nuclear submarine unit, including construction of land-based prototype at Dounreay will continue despite the recent data-sharing agreement with the U.S.

MODIFICATION of the three civil U.K. nuclear power stations for an increase in plutonium production " in no way reflects any change in the assessment of the economics of British nuclear power stations," Mr. Reginald Maudling, Paymaster General, told the Commons recently. He commented that the decision to produce more plutonium was a purely military one. There has been some misapprehension overseas that Britain's nuclear power stations would not be as economic as originally envisaged. Mr. Maudling's statement was made to rebut any rumour to this effect.

GERMAN government officials, industrialists and scientists visited the Bradwell site on July 18 at the invitation of Nuclear Power Plant Co.

Australia

CONTRACTS for the sale of £A6 million-worth of uranium concentrate from South Alligator River area of the Northern Territory to U.K.A.E.A. were about to be signed as this issue went to press. The Australian companies concerned are United Uranium and South Alligator Uranium.

Africa

SOME URANIUM is to be supplied direct to the U.K. in future, Dr. van Rhijn, Minister of Mines, announced in Cape Town on August 14. This year the value of the Union's production of uranium was expected to create a new record, he said. Supplies of uranium oxide to the Combined Development Agency were being increased to 6,200 tons a year. Any surplus would be sold direct to the U.K.

Belgium

PLANS for a nuclear power station to be jointly owned by the Dutch Limburg Electricity Company and two Belgian electricity concerns are being discussed. It is envisaged that the plant would be installed at Mol near the Dutch border.

Finland

YDIN EXPONENTIAL PILE came into operation on May 21. This sub-critical assembly is located at Finland's Institute of Technology at Otaniemi near Helsinki. The pile has been designed and financed by Ydin Nuclear Power Association which has been formed by a group of the largest privately owned companies. The assembly is a truly international effort—1½ tons of British uranium, American graphite and instruments, a neutron source supplied by the U.S.S.R. and Finnish (Warkaus Engineering Works) contributions in the form of a reactor tank in aluminium, support structure for the fuel elements and aluminium fuel cans. Mr. D. Jåfs of A. Ahlström Osakeyhtio was responsible for the nuclear side of the assembly. The reactor tank is 59 in. in diameter by 66 in. high and there are 112 5-ft-high 1-in.-diameter fuel elements. The moderator is ordinary water and the bottom reflector is graphite.

France

THE SECOND PILE at Marcoule, G.2, diverged on July 21. Although essentially developed to produce plutonium, G.2 has a thermal rating of more than 150 MW and the reactor powers a turbo-alternator giving between 30 and 35 MW. The pile will produce about 40 kg of plutonium per year.

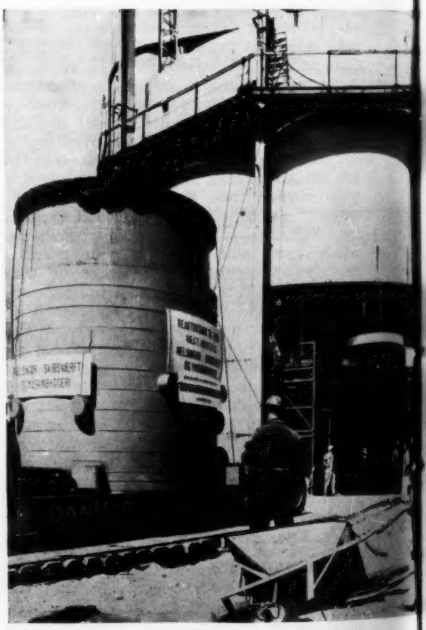
German Democratic Republic

PARTICLE ACCELERATOR with a capacity of 25 MeV has just been commissioned at the Rossendorf research centre.

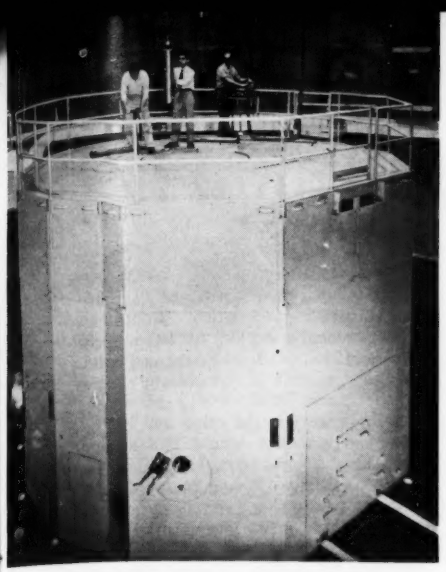
German Federal Republic

THE 50-kW RESEARCH REACTOR supplied by Atomics International to the Institute for Nuclear Research in West Berlin went critical on July 24. Fuelled with enriched uranium, supplied through the U.S. " Atoms for Peace " programme, the solution-type reactor is the fourth exported by A.I. to go critical.

REACTOR GRANT of $350,000 towards the cost of the research reactor constructed for Munich Technical University has been made by the U.S. The reactor, a 1 MW water-cooled and moderated pool type went critical in October, 1957. It was supplied by A.M.F. Atomics at a total cost of $3 million.



The 46-ton steel tank designed by Head Wrightson Processes for the Danish research reactor at Risø is shown here after completing the journey from Elsinore shipyard.



A novel 1 MW research reactor at the Massachusetts Institute of Technology went critical in June.

NEW SOCIETY, " Atom für den Frieden E.V.," was formed on July 14 to spread information on peaceful uses of nuclear energy throughout W. Germany.

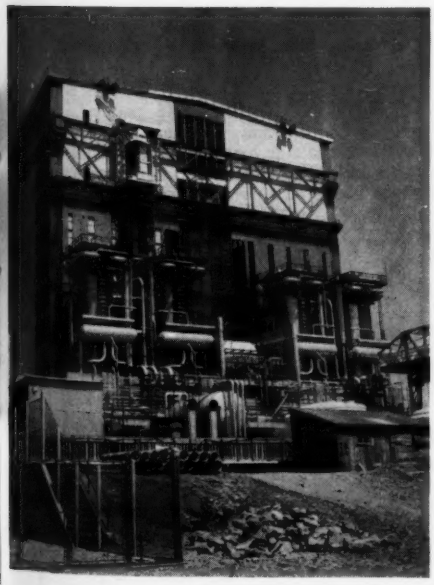
NUCLEAR POWER STATION of 15 MW planned by Rheinisch-Westfälische Elektrizitätswerke will be operated by a new company. The station will be located at Kahl, near Aschaffenburg.

DEGUSSA, of Frankfurt, has received orders from the Indian A.E.C. and from two Italian groups for high vacuum melting plant used in the manufacture of fuel elements.

Greece

U.S. GRANT of $127,000 has been given to the Greek A.E.C. towards the cost of a nuclear engineering laboratory. Main item of equipment will be a sub-critical assembly including a stainless steel tank and complete lattice assembly. Fuel for the assembly will consist of 2,500 kg of canned natural uranium slugs supplied under the existing Greece-U.S. agreement for co-operation.

France's second power reactor, G2 at Marcoule, went critical on July 21. When preliminary tests have been completed later this year the pile will have a thermal output of more than 150 MW.



Israel

REACTOR SIMULATOR, the first installed in Israel, is now in operation at Israel Institute of Technology in Haifa. The instrument, which was built in the U.S., was donated to the Institute by a friend of the Institute living in Los Angeles.

Italy

U.S.A.E.C. has given the Comitato Nazionale per le Ricerche Nucleari a gamma irradiation unit equipped with a cobalt 60 radiation source. The equipment is intended for research at the Botanical Institute of the University of Pisa.

Netherlands

DUTCH INSURANCE GROUP, in conjunction with foreign insurance concerns who have offices in Holland, have founded an insurance pool against damage from the peaceful uses of nuclear energy. So far 9.5 million guilders has been provided for risks of material damage and a further 6 million guilders for third party risks.

Norway

ZERO-ENERGY ASSEMBLY for the Jener Institute will be a pool-type with natural uranium as fuel and heavy or light water as moderator and coolant. The work will be carried out by the National Institutt for Atomenergi (I.F.A.) and Norwegian companies forming the Noratom group. The object of the reactor is to assist in the development of boiling-water reactors for marine use.

Portugal

NEW COMPANY has been formed by leading Portuguese companies to exploit industrial applications of nuclear energy. Complete title is Companhia Portuguesa de Industrias Nucleares, SARL. Capital is 100 million Escudos.

Puerto Rico

GROUND-BREAKING CEREMONY leading to the construction of a nuclear research centre for Puerto Rico was attended by Dr. Milton S. Eisenhower, brother and personal representative of President Eisenhower on July 26. The laboratory facilities and reactor building will be adjacent to the Mayaguez campus of the University of Puerto Rico. A 1 MW (T) pool-type research reactor will be designed and installed by A.M.F. Atomics. The facilities are scheduled for completion in 1960.

Sweden

URANIUM EXTRACTION PLANT with an annual output of 120 tons of uranium from 900,000 tons of crude schist is planned by the Swedish Atomic Energy Company. To be called the Ranstad Works, the plant will cost about 125 million kroner. The schist deposits are in the Mt. Billingen area in West Sweden. Work will start this autumn and is expected to be completed by 1962.

Switzerland

BUDGET of £3.2 million for the Swiss atoms-for-industry programme is proposed by the government. The money will be spent in training scientists and purchasing equipment.

United States

RESEARCH REACTOR costing $400,000 will be presented to St. Paul's University, Tokyo, if the General Convention of the Protestant Episcopal Church of the United States agrees to a recommendation of its nuclear commission next month.

REACTOR SCHOOL for Oak Ridge National Laboratory employees and those of other Union Carbide Nuclear Co. installations will re-open in September with a new training programme.

STATES MARINE LINES is negotiating with the U.S.A.E.C. and the Maritime Administration for a contract to serve as the general operating agent for the N.S. Savannah.

A.E.C. is studying the practicability of producing both power and radioisotopes from nuclear explosions.

BILL calling for construction of a nuclear powered icebreaker at a cost of more than £21 million was vetoed by President Eisenhower. He commented that the icebreaker was not required and that the Bill did not take into account the present fiscal situation of the government.

BABCOCK AND WILCOX CO. have been selected by the A.E.C. and the Maritime Administration to train the engineering officers of N.S. Savannah, the projected nuclear-powered merchant ship. The educational programme will cost $150,000.

REACTOR with unusual features has been commissioned at Massachusetts Institute of Technology. Similar in type to Argonne's CP-5, the 1-MW M.I.T.R. has a medical therapy room immediately beneath the reactor core with facilities for streaming neutrons from the reactor to patients. M.I.T.R. uses enriched uranium 235 and is heavy water moderated and cooled. Neutron flux is 10^{13} n/cm^2, sec.

NUCLEAR SEAPLANE. An extension of engineering studies on a nuclear seaplane project at the Martin Baltimore Division was announced recently. The company has received a contract worth more than $385,000 from the U.S. Navy. The studies are directed towards the use of an existing British seaplane, the Saunders-Roe Princess, as a test aircraft.

PLUTONIUM for sub-critical assemblies owned by foreign countries can now be obtained from the U.S.A.E.C. Hitherto a standard " Atoms for Peace " agreement has limited the supply of plutonium to 10 grams. The quantity has now been raised to 260 grams to permit the construction of plutonium/beryllium neutron sources for the sub-critical assemblies.

A.L.P.R.—the Argonne Low Power Reactor, prototype of a reactor designed for power production and space heating at remote military stations—went critical on August 11 at the National Reactor Testing Station, Idaho Falls, Idaho. The A.L.P.R. is a direct cycle, natural circulation boiling water reactor fuelled with enriched uranium and water moderated. The reactor will generate 260 kW of electricity and 400 kW of heat. Thirteen companies have offered to operate A.L.P.R. on behalf of U.S.A.E.C.

THE FIVE MEN who were exposed to radiation in a criticality incident at the A.E.C. Y-12 plant at Oak Ridge on June 16 and were detained in hospital have been released.

Orbits in Industry

THE knowledge that papers at the forthcoming Geneva Conference (of which rumours may have reached you) will total some 2,300 is, as one would imagine, arousing deep feelings of no enthusiasm amongst those ink-stained wretches whose task it is to purvey the substance to their readers as predigested concentrate, digest of extract of abstract or dabstract, for short. It takes, so they say, 250 lb of rose petals to produce one ounce of attar of roses. If the same principles can be applied to Extract of Geneva, it should be pretty good stuff, but the distillers are not going to have much fun. Conference, wrote Francis Bacon, makyth a ready man. . . . Ready for what?

The "Lunatics"

One longs, sometimes, for the comparative tranquillity of the scientific life of a couple of centuries ago, when Priestly (*not* J.B.) Baskerville, Josiah Wedgwood, Galton, and other distinguished men used to congregate at Matthew Boulton's house at the meetings of the Lunar Society, which held its meetings at the full of the moon, so that its members could return home in comparative safety. . . . "It does not appear," says Dickinson, "that any definite work was done by the Society, such as we see today, when we cannot meet without some person being constrained to give a paper. . . ." At the present moment, that seems a masterpiece of understatement.

Science Fiction

The Lunar Society seems to be being revived in a different guise. By the time this appears in print there seems to be little doubt that a lot of people whose thirst for scientific knowledge outruns their sense of proportion will have made at least a spirited attempt to discharge rockets at it, thus adding considerably to our knowledge of . . . something or other.

Nature, as we know, has been blamed for copying art, and life seems to be determined to copy science fiction. The recent voyage of the "Nautilus" is a good example. If Jules Verne's copyright had not expired, the least that Commander Anderson could reasonably expect would be a stiff letter from his solicitors.

Under, Not Up

Let it not be thought for one moment that Tangent has any intention of belittling the achievement of the "Nautilus." When one considers the difficulty of navigating in broad daylight, between say, Southend and Bradwell, without going ashore on the Maplins, the performance of the "Nautilus" in navigating "blind" in an area where the magnetic compass is useless and even the gyro commences to play tricks, is seen for what it really is: a tremendous achievement.

Incidentally, Commander Anderson carries a volume of *Nuclear Engineering* aboard. We have so often been accused of being up the pole that to go underneath it makes a pleasant change.

Millwrights Up-to-date

To many, the word "millwright" conjures up a vision of a fourteenth-century type, in doublet and hose engaged in wreaking (or wroughting?) a mill. To Tangent, it always brings a vision of an elderly bod in faded blue overalls tut-tutting over three missing teeth on a cast iron gearwheel. Having tutted as requisite, he then drilled rows of holes in the wheel, tapped them, screwed in steel studs, filed them up into the shape of teeth, and then departed with his straw toolbag and red-spotted-handkerchief-wrapped dinner, to the next job.

Millwrights, except in the more conservative companies, are called Plant Engineers nowadays, and are vastly more scientific types. They use slide-rules and card index systems and some of them even manage to get home at night. For four years, now, the University of Nottingham has been holding courses for plant engineers, and an announcement of the fifth course appears elsewhere in this issue. The syllabus, which has been compiled from the requests of those who attended the last course, gives some idea of the wide variety of interests of the modern plant engineer. Planned maintenance systems, cranes, paints, boiler plant, oil fuel, adhesives, and additives, one would expect to find, and it is gratifying to see that the use of isotopes has also found a place. Practical measures to meet the Clean Air Act, and vibrations in buildings are a little more unexpected—as is a forum on the "Impact of the European Common Market on the Engineering Industry," which one would have thought was a little bit off the beaten track for plant engineers.

A surprising omission from the syllabus, however, which Tangent would have thought of paramount importance, is a lecture (or even two) on Personal Relationships. Most plant engineers do not expect to Win Friends and Influence People (although they can influence a whole lot by deciding to do a back-end clean on the heating boiler in November) but some of them feel, rather wistfully, that it would be nice to keep a few of the friends they originally had, and still be able to say "No."

The Little Black Book

Everybody who has ever been friends with a plant engineer seems to expect that the entire resources of the Maintenance Department will be at his disposal just as and when. Important people suddenly decide to have their office roof removed and replaced with Vita-Glass; slightly less important people feel that their office would be much more convenient at the other end of the works, or that they would like a new desk, or a particularly expensive fluorescent fitting. Trying to say "No"—because funds won't run to it or men are wanted for more important work—can be quite a problem.

There is, of course, a simple solution, in the form of the Little Black Book, which is carried in the pocket and whipped out for every would-be customer. No matter how impracticable or fat-headed the request may be, full particulars are noted, with the most solicitous application to detail. The book is burned every Friday night, and a new one started on Monday morning. It is a method that seldom fails.

DR. FINAGLE'S LAWS—3

Second Law of Revision

The more innocuous the modification appears to be, the further its influence will extend and the more plans will have to be redrawn.

Third Law of Revision

If, when completion of a design is imminent, field dimensions are finally supplied as they actually are—instead of as they were meant to be—it is always simpler to start all over.

Corollary I: It is usually impractical to worry beforehand about interferences—if you have none, someone will make one for you.

More Nashery

Oak Ridge biochemists have produced a pill which, it is stated, will enable human beings to resist double the present lethal dosage of radiation. The material rejoices in the name of S2-aminoethylisothiuronium bromide hydrobromide which seems a little ostentatious to say the least of it. Wondering what Ogden Nash would have thought about it, we came to the conclusion that he might have felt that:—

I have tried and tried till my brain is numb
To find rhymes for aminoethylisothiuronium
And given thanks (with something approaching panic)
That, at school, I never got past Inorganic;
The only people who could cope with this stuff, Tosh,
Would be Welshmen living at Llanfairpwllgwyngyllgogerychwyrndrobwilllantysiliogogogoch
And I think that being shot full of neutrons is betterer
Than having to ask a chemist for amino . . . etcetera.

Tangent

Personal

Cmdr. W. Anderson.

Mr. C. A. Adams.

Mr. T. Giusti.

Appointments

Mr. John McCone has now been appointed chairman of the U.S. Atomic Energy Commission by **President Eisenhower.** His nomination as a member of the Commission was approved by Congress during July.

Mr. C. A. Adams, B.Sc., F.Inst.P., chief of trials and safety of the United Kingdom Atomic Energy Authority Weapons Group at Aldermaston, as chief nuclear health and safety officer of the Central Electricity Generating Board.

Sir Francis Evans, G.B.E., K.C.M.G., and **Mr. L. W. Cole,** B.Com., to the board of directors of Dewrance and Co. Ltd., Engineers, to fill vacancies created by the resignations of **Admiral Sir Cecil Harcourt,** G.B.E., K.C.B., and **Mr. Hector McNeil,** B.E., M.I.Mech.E., M.I.E.E.

Rear-Admiral Helio Lopez, president of the Scientific Research Committee of the Forces and consultant to the National Council for Scientific and Technical Research, succeeds **Ing. Capitain O. A. Quihillalt** as president of the Comision Nacional de Energia Atomica, Argentina. Capitain Quihillalt and five other members of the Comision resigned when President Frondize entered office on May 1.

Takeo Miki succeeds **Matsurato Shoriki** as Minister for the Japanese Atomic Energy Commission, the Economic Planning Council and the Scientific and Technical Agency.

Mr. A. F. Street as director and chairman of the Micanite and Insulators Co. Mr. Street, who is a director of Siemens Edison Swan and other A.E.I. companies, has also been appointed a director of British Tego Gluefilm, a wholly owned subsidiary of M. and I.

Mr. Henry L. Lloyd, O.B.E., M.C., B.A.(Cantab) as general manager of Roballo Engineering Co., a new British company with offices at 43 Dover Street, London, W.1.

Miss D. Smith.

Mr. A. F. Street.

Mr. W. R. Cooper, assistant managing director of Lloyds (Burton), **Mr. W. H. Nicklin,** sales manager, **Mr. F. Clymer,** A.M.I.Mech.E., A.M.I.Prod.E., foundry manager, and **Mr. W. L. Beasley,** production manager, as directors of F. H. Lloyd and Co. **Mr. M. C. Lloyd,** M.B.E., assistant managing director of F. H. Lloyd and Co., and **Mr. F. Clymer,** A.M.I.Mech.E., A.M.I.Prod.E., foundry manager, as directors of Lloyds (Burton).

Mr. Roger M. Smith, formerly superintendent, production, planning and control branch, Atomic Energy of Canada, as director of safeguards, International Atomic Energy Agency.

Mr. James T. Johnson as sales manager of Radiation Counter Laboratories, Inc., Skokie, Illinois. **Mr. Roland M. Waters** as assistant sales manager.

Mr. F. F. Dunkin as U.K. sales engineer for Venner Electronics.

Mr. D. M. Jinks as joint managing director of Cleco Electric Industries.

Mr. J. P. Harvey and **Mr. F. W. Shorter** as directors of a new company, Servo Units.

Dr. A. T. Starr, M.A. (Cantab), Ph.D., M.I.E.E., succeeds Dr. Nyman Levin as chief of research and development, Rank Precision Industries.

Mr. P. W. Faulkner, O.B.E., general manager of Plessey's Chemical and Metallurgical section as a director and general manager of Plessey International.

Mr. G. H. Walton, joint general manager of British Insulated Callender's Cables with **Mr. O. J. Crompton,** relinquishes his executive duties on reaching retirement age. He remains a director. Mr. Crompton becomes general manager. **Mr. G. A. Rendle** becomes deputy general manager, but continues as manager of the power cable and telecommunication cable contracts dept. **Mr. E. T. Q. Davies** as a director in addition to continuing as manager of the overhead line contracts dept. **Mr. F. B. Kitchin** retired as a director of B.I.C. Construction on June 30.

Mr. K. Elphinstone, M.B.E., as export manager of E.M.I. Electronics.

Miss Dorothy Smith of the motor engineering dept., Metropolitan-Vickers Electrical Co., has been elected to full membership of the Institution of Electrical Engineers. Until now no woman has achieved this distinction since **Mrs. Ayrton** in 1899.

Dr. J. H. Watson as president-elect of the Institution of Mining and Metallurgy.

Mr. G. Millington, M.A., B.Sc., M.I.E.E., as chairman-elect of the radio and telecommunications committee of the I.E.E.

Mr. John Collins, commercial manager of English Electric's Liverpool and Netherton works, as chairman of the Merseyside and N. Wales section of the I.E.E.

Mr. P. S. Beale as a director of British Oxygen.

Mr. R. J. Barritt as chief executive, engineering division, British Oxygen.

Mr. W. E. Preston as technical representative of Foxboro-Yoxall.

Mr. O. W. Minshull as general manager of the power cables division of British Insulated Callender's Cables.

Mr. E. F. Weisner as project engineer for the Piqua reactor development programme of Atomics International. Mr. J. F. Trevillyan as project administrator. Dr. C. A. Trilling, group leader for organic moderated reactors has in addition been appointed project engineer for A.I.'s advanced OMR programme.

Tours

Mr. James A. DeShong, Jr., head of the control section of Argonne's reactor engineering division, will aid the Norwegian team responsible for initial operation of the Halden boiling heavy water reactor (H.B.W.R.).

Dr. Leonard I. Katzin, senior chemist in Argonne's chemistry division, is to undertake a year's research in physical inorganic chemistry at A.E.R.E., Harwell.

Awards

Commander W. R. Anderson, of *U.S.S. Nautilus*, was presented with the Legion of Merit by President Eisenhower in Washington on August 8. The citation referred to the fact that "under his intrepid leadership Nautilus pioneered a submerged sea lane between Eastern and Western hemispheres." The President also conferred a presidential unit citation on the crew.

Admiral Lewis Strauss, who resigned as chairman of U.S.A.E.C. on June 30, was awarded the Medal of Freedom by **President Eisenhower** in a White House ceremony on July 14.

Sir John Cockcroft has been awarded the 1958 Niels Bohr Gold Medal for special contributions towards peaceful uses of nuclear energy.

Obituary

Nuclear Engineering records with regret the death of the following:—

Professor Frederic Joliot-Curie, the distinguished French physicist, died in Paris on August 14. He was 58. After training at the

Ecole de Physique under Langevin, he moved to the Institut de Radium in the 1920s. There he met Irene Curie, daughter of Pierre and Madame Curie, the discoverers of radium. They married in 1926. Eight years later they presented to the French Academy of Sciences a joint paper announcing the discovery of artificial radioactivity. This paper won a Nobel award. Following the Second World War, Joliot-Curie became head of the Centre National pour la Recherche Scientifique and also High Commissioner for Atomic Energy. In April, 1950, he was dismissed because of his membership of the French Communist Party. Most of the remaining years were devoted to support of the World Peace Council of which he became president.

Dr. George Braxton Pegram, vice-president emeritus of Columbia University, died in New York on August 12. He was 81. In 1941 he established the first nuclear pile at Columbia. After the war he was appointed as a director of Oak Ridge Institute of Nuclear Physics and he helped to establish Brookhaven National Laboratory. Last year the Duke of Edinburgh presented him with the first Karl Taylor Compton gold medal for physics.

Mr. Tito Giusti, founder of T. Giusti and Sons, on July 23 at the age of 86.

Mr. Gordon Dean, a former chairman of the U.S.A.E.C., was killed in an aircraft crash at Nantucket on August 16.

Conference Secretaries

An international team of scientific secretaries from 13 countries has been appointed by United Nations to assist in the preparation of the International Conference on the Peaceful Uses of Atomic Energy in Geneva from September 1 to 13. The team began work a few months ago at U.N. Headquarters, but is now located in Geneva. The personnel appointed, and their countries of origin are listed below:—

Argentina: Cesar Sastre.
Austria: Dr. Traude Bernert.
Belgium: Miss Renee Bovy.
Canada: Thomas G. Church, Professor D. Harold Copp.
Czechoslovakia: Ivan Ulehla, special assistant to the conference secretary general.
France: Pierre Yves Tanguy, Valery Ziegler.
Germany: Dr. Gerhard Matz.
India: Homi N. Sethna, deputy conference secretary general; A. S. Rao.
Israel: Israel Dostrovsky.
Italy: Dr. Claudio Garavaglia.
Japan: Hiroshi Fukunaga.
Spain: Professor Carlos Sanchez del Rio.
United Arab Republic: Afaf A. Sabri.
United Kingdom: Terence E. F. Carr, Fred Hudswell, William Brian Woollen.
U.S.A.: Frank Bruce, Thomas Coor, David Okrent.
U.S.S.R.: Aleksander Nikitich Efimov, Ivan Dmitrievich Rozhansky, Gavril Sergeevich Strelin.

Meetings and Courses

Modern Techniques for the Engineer. The University of Nottingham is holding a course of 16 meetings for works, plant and production engineers, on Tuesday evenings from October 21, at 7 p.m., each lecture lasting one hour and followed by an hour of open discussion. Subjects covered are maintenance, lifting apparatus, paints, oil burners and boiler plant, building vibrations, the Clean Air Act; measurement, use of isotopes, automatic control, instrumentation, adhesives, additives and the European common market. Fee for the course is £6 6s. for transferable registrations to companies or £5 5s. for non-transferable registrations for individuals. Transport from city centre is included.

Golden Jubilee Autumn Meeting of the Institute of Metals. The Institute has recently published a programme of its Autumn Meeting, which is to take place in Birmingham from September 22 to 26 this year. Many visits to companies in the Birmingham area are being arranged. Among the speakers will be Dr. W. M. Lomer and Dr. A. H. Cottrell, of A.E.R.E., Harwell, the subject being "Looking at Dislocations." Further details can be obtained from S. C. Guillan, Secretary, Institute of Metals, 17 Belgrave Square, London, S.W.1.

Post-graduate Courses: The Department of Metallurgy, College of Technology, Gosta Green, Birmingham, proposes to offer a post-graduate course on the metallurgy of nuclear power materials during the autumn term commencing in October, 1958. Ten lectures will be given on successive Tuesday evenings beginning on October 7. The fee will be £2 2s.

Second Conference on Analytical Chemistry in Nuclear Reactor Technology. This conference, sponsored by the Analytical Chemistry Division of Oak Ridge National Laboratory, will take place from September 29 to October 1 at the Civic Auditorium, Gatlinburg, Tennessee.

Industrial Notes

The Rio Tinto Group, largest producer of uranium in the free world, has brought eight of the largest mines into production in a very short space of time.

In Canada the group controls Algom, Pronto, Northspan and Milliken Lake. These properties, which are all situated in the Algoma-Blind River area, comprise seven mines and treatment plants whose combined milling capacity totals 19,500 tons of ore per day, representing an output in terms of metal equivalent of over 5,000 tons of uranium per year. These companies have contracted to supply a large part of their output until 1962, or in some cases 1963, to the Eldorado Mining and Refining Company, Ltd., which acts as the Crown purchasing agent and passes the group's Canadian output to the U.K.A.E.A. and the U.S.A.E.C. either in the form of uranium oxide (U_3O_8) or up-graded feed materials. The Rio Tinto Group's Canadian properties hold supply contracts totalling more than $620,000,000.

In Australia the group controls Mary Kathleen Uranium, Ltd. This mine, the largest in Australia, will be supplying its total output of uranium concentrates to the U.K.A.E.A. under a contract which is expected to last between eight or nine years. The mine is now in full production and is treating 1,000 tons of ore per day, equivalent to an annual output of about 400 tons of uranium metal.

The group's Canadian properties have also large reserves of thorium, which is found in association with uranium in the Blind River ores. Rio Tinto and Dow Chemical of Canada Ltd. recently formed a joint company, Rio Tinto-Dow Limited, which will undertake manufacture of thorium compounds as a by-product of the group's uranium operations. Rio Tinto-Dow is also studying the possibility of producing high-grade uranium compounds for use in the manufacture of reactor fuels.

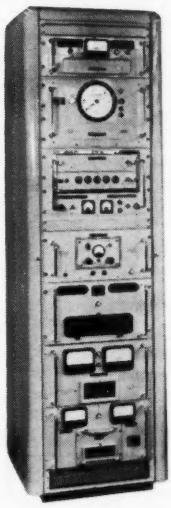
Savage and Parsons and the mechanical division of **General Mills Inc.,** of Minneapolis, are to form a joint company to design and manufacture remote manipulators. In addition to mechanical and powered systems the new company will develop reactor fuel loading and unloading systems, reactor maintenance systems and other auxiliary protective equipment. No announcement has yet been made regarding the name of the new company which will presumably be registered in Great Britain.

The Electronic Computer Exhibition, the first of its kind in Europe, is to be held under the patronage of The Duke of Edinburgh at Olympia, London, from November 28 to December 4, 1958. Concurrently with the Exhibition there will be a Business Computer Symposium.

The exhibition and symposium have been organized at the instigation of the National Research Development Corporation by the Electronic Engineering Association and the Office Appliance and Business Equipment Trades Association. About 40 British companies have already taken space. Further details of the exhibition and symposium can be obtained from Mrs. S. S. Elliott, M.B.E., Electronic Computer Exhibition and Business Symposium, 11-13 Dowgate Hill, London, E.C.4. Telephone, Central 7771-2.

Mitchell Engineering have now concluded a formal contract with **Saunders-Roe** for an 8½-month feasibility study on an 80,000-ton nuclear submarine tanker. Last autumn Mitchell asked Saunders-Roe to "examine the possibility" of such a tanker. The conclusion of a contract presumably means that the project has shown promise. Although no official announcement has been made about the type of reactor envisaged, Mitchells have an agreement with A.M.F. to construct boiling water power reactors.

Vitro Corporation of America has formed Vitro Italiana, S.p.A., an Italian subsidiary with offices in Rome and Milan. Vitro Italiana's activities will include design engineering and construction management of nuclear facilities, processing plants, refineries and petro-chemical plants. Two nuclear projects are currently under negotiation with the Italian government. Principal offices are located in Milan at Piazza della Repubblica 12. The Vitro Italiana directors include:



For experimental work in connection with the ADAM reactor at Vasteras, A.S.E.A. have ordered neutron flux measuring equipment from General Radiological. The photograph above shows a typical instrument rack.

J. Carlton Ward, Jr., president of Vitro Corporation of America; Vittorio E. Rimbotti of Milan; and Norman A. Spector, Ralph L. Brown and William H. Denne, Jr., executives of Vitro International.

Gammax, of Cecil House, 47-51 Wharfedale Road, King's Cross, London, N.1, have introduced a new radiographic inspection service for the examination of welds, castings and machine components. Field inspection engineers are available for on-site operations and laboratory testing facilities are provided. The company manufacture a range of gamma and X-ray equipment and accessories. The non-destructive inspection service is under the personal supervision of R. J. Ford.

Roballo Engineering Co., a new British company, has been granted exclusive marketing rights in the U.K. for Roballo ball-bearing slewing rings. The company, which has offices at 43 Dover Street, London, W.1, will also market large-diameter wire-race ball bearings.

The Beryllium Corporation of Pennsylvania has recently inaugurated a plant for the fabrication of beryllium metal at Hazleton. Previously, the only beryllium powder metallurgy fabrication plant in the U.S. was owned by the U.S.A.E.C.

Short Bros. and Harland have supplied an analogue computer for use in the Institute of Automation of the Polish Academy of Sciences, Warsaw.

Ferranti are to supply a high-speed Mercury electronic digital computer to the Centre d'Etudes pour les Applications de l'Energie Nucleaire at Mol. Mol is the seventh nuclear research centre to order a Mercury.

Servo Units has been formed by Harvey Electronics to take over the manufacture of the existing range of Harvey servos. The first new product of the company will be a series of fully transistorized power servos giving a stalled torque output of up to 5 lb/ft. Address of the new company is 273 Farnborough Road, Farnborough, Hants.

Cofinatome—Compagnie de Financement de l'Industrie Atomique—has been formed by various French merchant bankers, among whom are the Banque de l'Union Parisienne, Rothschild Frères and the Union Europienne Industrielle et Financière, for the purpose of forming companies within the whole range of the atomic energy field.

Metropolitan-Vickers held their seventh summer school during July. The course was attended by more than 70 professors and heads of university departments.

Fielden Electronics have established a Midland office at 51 Bradford Street, Walsall, Staffs. Telephone: Arboreteum 55343. Mr. F. Bernard Price is the manager.

John Thompson were recently hosts to four Russian industrial technicians headed by Mr. V. I. Baranov, deputy director, department of turbine and boiler construction, U.S.S.R. The visit was arranged through the Water Tube Boilermakers Association, who are shortly to send a British delegation to the U.S.S.R.

Csepel Radioisotope Laboratory in Budapest is pioneering the industrial application of radioisotopes in Hungary. The current programme includes the investigation of thick walled steel castings and of welding seams. Transluminations are carried out with various substances such as thulium-170, iridium-192, caesium-137 and cobalt-60.

Honeywell Controls recently opened their new head office at Greenford, Middlesex. The ceremony was performed by Mr. Harold Sweatt, chairman of the Honeywell organization.

Rocol, manufacturers of molybdenized and other special lubricants, have appointed International Agencies and Machinery Co., of 2315 Cambie Street, Vancouver, B.C., as their agents in British Columbia and W. R. Watkins Co., 41 Kipling Avenue South, Toronto 18, as agents for all Canada except British Columbia.

National Research Corporation of Cambridge, Massachusetts, announces the commercial production of very high purity tantalum metal. Production is currently at the rate of 30,000 lb/year.

Metal Hydrides, Inc., of Beverly, Massachusetts, are producing two new grades of high-purity zirconium hydride (ZrH_2) for nuclear applications (MHI grade R) and for general applications (MHI grade C). Grade R, which is suitable as a moderator contains less than 0.01% hafnium.

Ad. Aurienna Inc., 85 Broad Street, New York, have been appointed exclusive export representatives for the Nuclear Electronics Corp. of Philadelphia.

Westinghouse Electric Corporation has received an order for a 384 MVA generator and its associated 325 MW turbine for a new station of the Arkansas Power and Light Co.

BS499C British Standard Welding Symbols. This specification differs from the normal run of B.S. specifications in that it has been produced as a wall chart. More than 20 types of weld symbols are given alongside their appropriate sections, and examples of the method of use for the complete specification of welds in the simplest possible manner. The charts can be obtained from the British Standards Institution, 2 Park Street, W.1, at 3s. unmounted or 6s. mounted.

Plannair's new factory at Leatherhead, Surrey, will add 15,000 sq. ft. of floor space to the company's existing capacity. The company makes climatic test chambers and high and low temperature cabinets.

Isratom, Israel Nuclear Engineering Co. has been formed by **Delek, Israel Fuel Corporation** to study industrial applications of nuclear engineering and the use of nuclear power for maritime transport.

Brush Beryllium Co. of Ohio have received an order worth $1.2 million for two beryllium core matrices for the high flux materials testing reactor, B.R.2, under construction at Mol, Belgium.

Titanium Metals Corporation of America and Deutche Edelstahlwerke of Kreseld, a member of the Thyssen group, have concluded an agreement enabling the German company to make titanium.

J. Stone and Co. (Charlton) report the introduction of new magnesium base alloys containing silver, rare earth metals and zirconium. Designated M.S.R. alloys, they have good casting qualities and perform well in tensile or short-term creep tests at elevated temperatures.

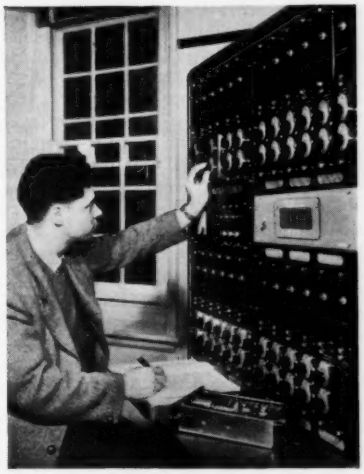
Address Changes

B. and K. Laboratories have acquired additional premises at Tilney Street, Park Lane, W.1. Telephone: Grosvenor 4567.

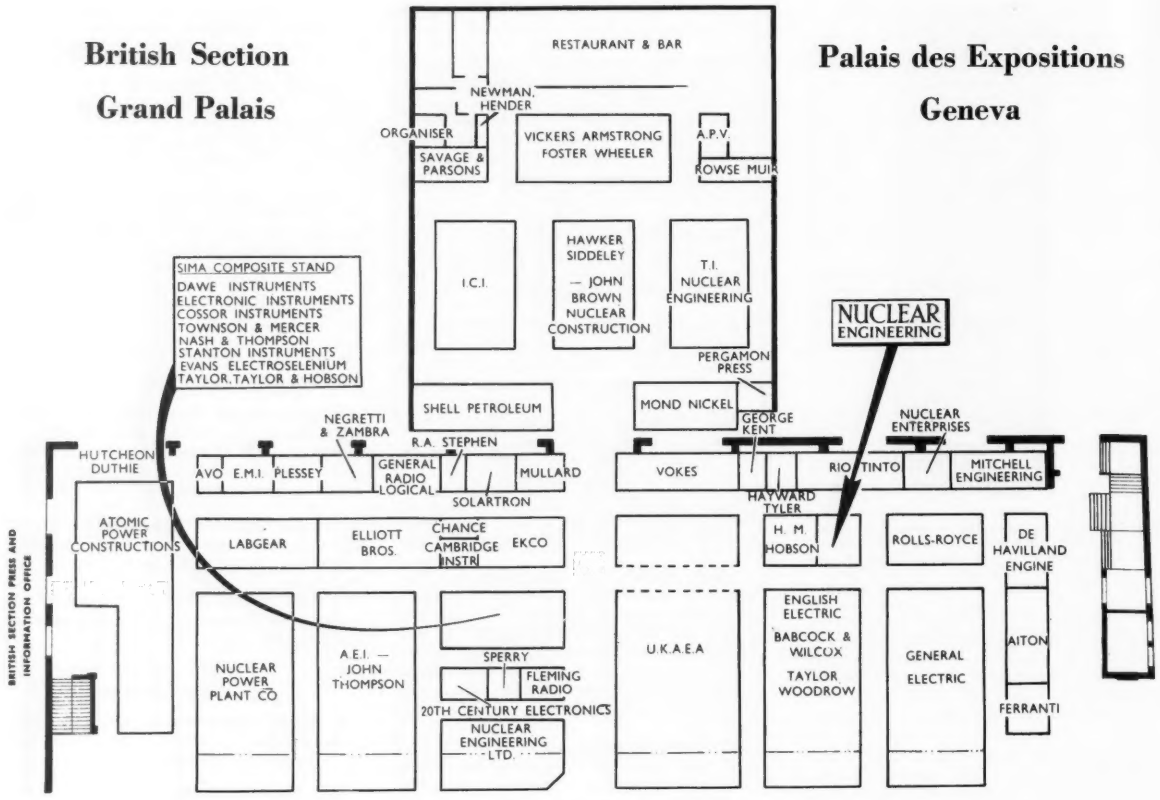
Opperman Gears have transferred their Northern office from Leeds to Manchester. The new address is 20 St. Ann's Square, Manchester, 2. Telephone: Blackfriars 6451. The manager is Mr. M. G. Marsh.

Bryan Donkin Co. have moved their London office to 25 Westminster Palace Gardens, Artillery Row, Westminster, London, S.W.1.

Cawkell Research and Electronics have moved to Scotts Road, Southall, Middx. Telephone: Southall 3702 and 5881.



Solartron process response analyser for nuclear simulator engineering research and nuclear reactor design applications. Units from this equipment are being shown at Geneva by Solartron.



British Exhibits at Geneva

Highlights of the Commercial Exhibition

IT is appropriate that of the 13 countries represented at the commercial "Atoms for Peace" exhibition at the Palais des Expositions in Geneva, Great Britain has by far the strongest representation—both as regards the number of exhibitors (80) and the total area of stand space (over 40,000 sq. ft.). But size alone is meaningless unless it is backed with the right sort of technical skill and manufacturing ability. For this reason the seven principal stands in the British Section have been designed with a common theme in mind—Britain's capacity to design and construct fuel and service economic nuclear power reactors anywhere in the world.

The largest stand in the Section is occupied by the **U.K. Atomic Energy Authority:** it is designed primarily to serve as an introduction to nuclear engineering in Great Britain. Another large stand, the British Press and information office, staffed by the **Nuclear Energy Trade Association's Conference,** offers on a collective basis full details of British companies' exhibits. N.E.T.A.C., incidentally, is primarily responsible for organizing the British Section at Geneva.

The other five large stands referred to are occupied by the British consortia specifically formed to build complete nuclear power stations. In these exhibits the constituent companies of the consortia show how individually each contributes its technological skill for the construction of a station through the medium of a co-ordinating central design team.

The Authority's stand follows closely on the pattern established at the German Industries Fair at Hanover earlier this year. Exhibits fall into three main groups: reactors, fuel services and isotopes. On the reactor side the exhibit tells of Britain's early lead in the development of Calder Hall, the establishment of the nuclear power programme and the work that has led up to the construction of four British nuclear stations ranging from 275 MW to 500 MW. The Authority's work on the advanced gas-cooled (A.G.C.), the high-temperature gas-cooled (H.T.G.C.) reactor scheduled for the 1970s; the gas-cooled heavy water reactor and the fast breeder reactor at Dounreay are also described.

The section of the A.E.A. stand concerned with fuel elements refers to the Authority's experience of manufacture built up over the past 12 years, examples being shown of early elements for GLEEP and BEPO. Development of the Windscale elements by I.C.I. and the fabrication of the Calder elements by Fairey Aviation are also depicted followed by examples of the fuel elements for the C.E.G.B. and South of Scotland Electricity Board stations. The fuel element story—well illustrated by some excellent photographs—also refers to the present work on new materials for the A.G.C. and the H.T.G.C. The exhibit explains that as a result of the accumulated experience in designing and manufacturing fuel elements the Authority can confidently offer any country a complete nuclear fuel service for power or research reactors. In addition it can provide facilities for processing irradiated fuel elements on a large scale.

The third section of the stand is devoted to isotopes, and again the story

is of a world-wide market and the Authority's ability to supply quickly a wide variety of radioactive and stable isotopes. The complete range of isotopes available is listed together with typical applications of many of them. Finally, the A.E.A. cinema is showing, continuously, films of British nuclear progress. A special feature of the equipment is the simultaneous transmission, to sets of earphones, of commentary in four languages.

Nuclear engineering begins with the mining of uranium ore, and uranium concentrate is the central exhibit of **Rio Tinto's** stand. The specimen on display contains over 80% uranium oxide (U_3O_8) in the form of sodium uranate. The Rio Tinto group, which has eight mines in Canada and Australia, has a combined annual production equivalent to 5,500 tons of uranium metal per year and is probably the largest producer of raw material in the free world. Through its association with the Dow Chemical Co., the group is also establishing in Canada a thorium plant for the production of salts of nuclear purity. The group's world-wide activities are highlighted by a large illuminated map on the stand.

Major British Contractors

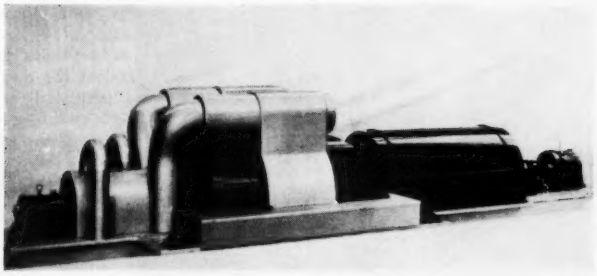
Next, the five consortia. The theme of the **A.E.I.-John Thompson** stand is "under one roof" and the exhibits have been carefully chosen so that all aspects of the group's nuclear work are featured. Principal exhibits are four models: the 275-MW Berkeley nuclear power station; 5-MW Merlin research reactor; a typical 150-MW single reactor station for export, and Sceptre III—the thermonuclear discharge chamber built by the group's Aldermaston research unit.

John Thompson have chosen to show the company's method of welding the 3-in. thick Berkeley pressure vessels on site together with examples of their intricate plumbing for the fast breeder reactor at Dounreay. **Met-Vick** feature their work in designing and building ZETA in collaboration with the A.E.A., and also the reactor control systems devised for Calder and Chapelcross. The company is also responsible for the 82.5-MW turbo alternators intended for Berkeley. **BTH**—another A.E.I. company—is displaying examples from the Berkeley reactor control system together with blowers and valves for the cooling system.

On the instrument side, **Sunvic Controls** and **Isotope Developments** show examples of nuclear instrumentation such as the memory drum, Barton meter, radioactive level detector and an auto-scaler. One other company, **Nuclear Graphite,** jointly owned by A.E.I. and Morgan Crucible, is also represented.

The aim of **Atomic Power Construction's** display is to demonstrate the group's ability to design, construct and commission atomic power stations of all sizes. A drawing office is included on the stand, complete with drawings of a power station for technical discussion.

One exhibit illustrates the company's research and development activities. It features welded specimens showing how rigidly welding is specified in various parts of a reactor. The exhibit also gives a broad picture of the laboratory layout and test facilities at the company's central laboratories with some indication of the scope of the research programme.

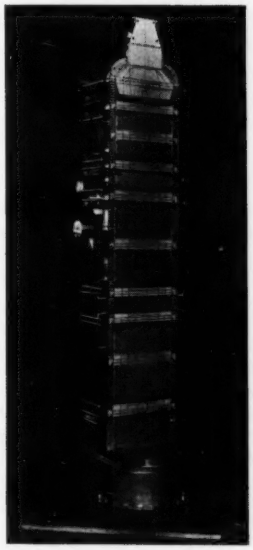


Model of a 100 MW turbo-generator for a nuclear power station (C. A. Parsons).

A model of a typical 500 MW station which could be supplied to the Central Electricity Generating Board of Great Britain is shown. Other exhibits portray the activities of the associated concerns in the application of atomic energy for peaceful uses. For example:—

Crompton Parkinson feature, in "exploded" form, a self-regulating alternator with Magnicon exciter mounted on the alternator shaft. **Elliott Bros.** display a Dynamaster high-speed servo-balanced electronic potentiometer recorder for operation from virtually any type of electrical input together with Swartout Autronic miniature all-electric automatic process indicator / controller / recorder units. Aluminium fabrications for atomic energy plant are shown by **Fairey Aviation** together with fuel containers for the Calder Hall and Windscale reactors.

International Combustion show component parts of a heat exchanger for a gas-cooled graphite moderated reactor. A sectional model of a complete heat exchanger is also featured. **Nuclear Civil Constructors** is represented by a photographic display of recent projects, including the plutonium separation plant at Windscale. Finally, on the A.P.C. stand there is a model of a Richardsons, Westgarth-Brown Boveri turbo-alternator set, together with condensing plant and feed-heating system, especially designed for the steam conditions of a modern nuclear power station. **Richardsons, Westgarth** are also exhibiting a bladed rotor of a research blower used for developing the compressors of CO_2 circuits for reactors.

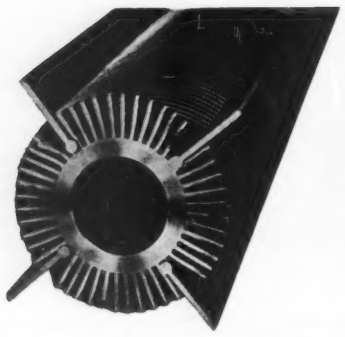


Sectional view of the heat exchanger model shown by International Combustion.

A 20 ft by 10 ft illuminated transparency dominates the **English Electric-Babcock and Wilcox-Taylor Woodrow** stand. The transparency dramatically illustrates the world's largest nuclear power station, the 500 MW Hinkley Point plant, in an advanced stage of construction. This transparency is believed to be the largest ever to be shown in any exhibition in Europe.

The picture reproduced in this way—an oil painting by Claude Buckle—shows the two reactor buildings approaching completion, with the 400-ton Goliath crane lifting into position the eleventh of the twelve steam-raising units and a stator for one of the six main 93.5 MW turbo-alternator sets about to be moved into the turbine house. Beyond the reactor buildings is seen one of the two cement batching plants. The painting thus symbolizes the contribution of each member company of the group, in civil, mechanical and electrical engineering.

An interesting contrast to the transparency is made by a 7-ft-square model of the station as it will appear when it is finished. Two other models depict a reactor and a steam-raising unit. The reactor model, 6 ft long, 3 ft 6 in. wide and 3 ft high, is sectional and shows details of the graphite-moderated core, the charge and discharge arrangements, the spherical pressure vessel, the biological and thermal shields, the coolant-gas circulation, and the steam-raising units. It is based on the reactors for Hinkley Point, each of which produces nearly 1,000 MW of heat, but its general design and construction are typical of reactors of smaller size which the group has developed. The model of a steam-raising unit is also sectional and stands 6 ft high on a base 2 ft 6 in. square. It demonstrates how higher steam output has been achieved, with relatively little increase in boiler size, by development of a greatly increased heat - exchange



Experimental helical finned fuel can. It is made of magnesium and fitted with splitters attached by a method patented by Fairey Aviation.

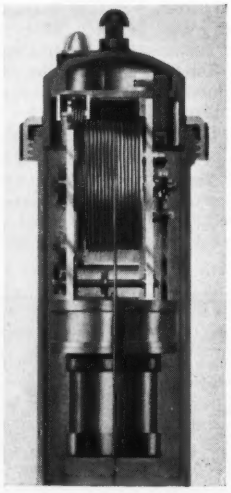
surface per unit volume of heat-exchanger.

Work which the group has done on other designs of gas-cooled graphite-moderated stations for overseas markets is also illustrated. For example, a display panel facing the visitor approaching from the central aisle carries impressions of designs for single-reactor stations with electrical outputs of 150 and 250 MW. Other display panels show typical examples of fuel element cans showing progress towards improved heat transfer properties in the finning; corrosion specimens of magnesium alloy, zirconium, low carbon steel, and titanium showing the effects of dry carbon dioxide gas on the metals after periods up to 10,000 hours and temperature of 500°C; fuel element support in zirconium; thermal cycling of standard "pippa-type" uranium through the alpha-beta transformation; and internal pressures on end cap welding. There is also a display of special techniques, with actual specimens, of welding of mild-steel and alloy-steel plates. Another exhibit shows examples of a special shock absorber device developed by the group's laboratories at Whetstone to prevent possible damage to the reactor structure from the accidental dropping of control rods.

Visitors to the **G.E.C. Simon-Carves** stand can walk inside a full-size model of the upper section of a Hunterston reactor. Entering the model through one of the gas-outlet ducts, visitors can see all the principal internal components, including the graphite core with its reflector, the boron-sandwich shield above the core, the double-shell pressure vessel, the fuel elements, control rods, and gas-sampling tubes for burst-cartridge detection equipment. Other important items displayed on the stand include a graphite completely impermeable to gases and highly resistant to gaseous corrosion which has been developed for nuclear applications by the G.E.C.'s Research Laboratories. Such a graphite offers potentialities as a fuel-canning material and as a moderator for use with liquid metal coolants. The impermeability of the material is demonstrated by a display of a graphite tube, the inside of which is charged, at a temperature well above 500°C, with carbon dioxide at a pressure of ten atmospheres while a vacuum is maintained at the outer surface.

An illuminated schematic diagram shows the layout of the high-temperature gas-cooled zero-energy critical assembly which is being built for U.K.A.E.A. at its research establishment at Winfrith Heath, Somerset. G.E.C. has been awarded the contract for a large part of the design and construction of this assembly, which will constitute the first step in the practical development of a new type of reactor. Because the fuel element design will permit the use of much higher operating temperatures, vastly improved steam conditions should be attainable and it may even be possible to operate gas turbines from such a reactor.

An animated diagram demonstrates the elaborate monitoring system incorporated in nuclear reactor designs, for the rapid detection of faults developing in fuel element cans. Gas samples are automatically taken every 40 minutes from each of the 3,288 fuel channels in the reactor, and their fission-products content measured and recorded. Any failure can be readily located and the faulty element removed before radio-activity of the gas-stream reaches a dangerous level.



Reactor control rod winding mechanism designed by Sperry Gyroscope.

A sectioned model shows the working of one of the Simon-Carves steam-raising units, eight of which are installed round each reactor of the Hunterston nuclear power station. Each steam-raising unit is designed to generate 143,100 lb (55,000 kg) of steam per hour at 580 p.s.i.g. (450 kg/cm²) and 700°F (370°C); and 70,850 lb (32,200 kg) of steam per hour at 150 p.s.i.g. (105 kg/cm²) and 660°F (350°C).

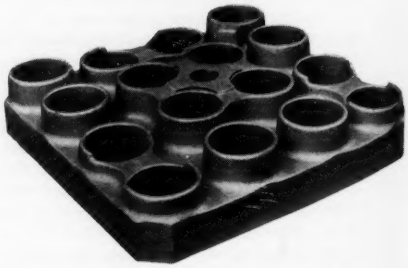
Applications of G.E.C. heavy alloy as a shielding material for the absorption of gamma radiation are also shown. This sintered tungsten-based alloy is used in the manufacture of such products as spheres for remote-handling equipment, isotope transport containers, shielding blocks for nuclear propulsion units and therapeutic apparatus.

A working demonstration is being given of the new G.E.C. heavy-duty power-operated manipulator, for handling radio-active and toxic materials. It is entirely remote-controlled, with no mechanical linkage of any kind between the control console and the arm, so that it can be used to handle materials at a considerable distance and, if necessary, in conjunction with closed circuit television.

The main exhibit on the **Nuclear Power Plant Company's** stand is a scale model of a complete nuclear power station. On this, there are two gas-cooled, graphite-moderated reactors sectioned and animated to display the working principles and layout, a fully equipped turbine house and switchyard. The model, which measures 12 ft square, includes the circulating water pumphouse, cooling pond and associated buildings. Telephones linked to commentaries in five languages describe the working principles of the station.

The eight member firms which make up N.P.P.C. are represented by models, animated displays and actual specimens of their products. Models are featured by **C. A. Parsons** (100 mW turbo generator); **Reyrolle** (typical feeder circuit of 132 kV duplicate busbar switching station and a full-size sectional head of a 275 kV air-blast circuit-breaker); **Head Wrightson** (counterflow induced draught-cooling tower of the type used in nuclear research stations in Great Britain, Australia and Denmark); **Clarke, Chapman** (steam-generating unit); **Strachan and Henshaw** (section of the graphite core of a gas-cooled nuclear reactor broken away to show an electrically controlled grab raising and lowering a fuel element); and **Sir Robert McAlpine and Sons** (model of the excavations and foundations for a nuclear reactor of the Bradwell type).

The exhibit by **Whessoe** is of a typical weld specimen which shows the high quality of welded seams of reactor pressure vessels. The specimen shows a horizontal hand weld on 4-in. plate. Representing the structural steelwork side, **Findlays** are featuring two typical box and girder sections as used in the turbine house at Bradwell.



Reactor guide pan casting in BS 592 B steel by A.P.V.-Paramount. Units similar to this will be supplied for Hunterston nuclear power station.

Reactor Development

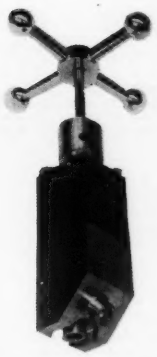
The five consortia are not the only British companies offering nuclear power reactors at Geneva. A scale model of a 17.5-MW (E) closed-cycle boiling-water reactor forms the centrepiece of **Mitchell Engineering's** stand. In association with the American Machine and Foundry Co. of New York (A.M.F.), Mitchell are main contractors for stations ranging from 17.5 to 140 MW (E). The centrepiece is flanked by illuminated flow diagrams of 17.5 and 70 MW (E) reactors. In addition enlarged photographs portray some current projects of the company and its subsidiary **Mitchell Construction.** These projects include the nuclear power station at Chapelcross and engineering work at Capenhurst, Springfields and Dounreay.

Vickers Nuclear Engineering combines the resources of three companies—**Vickers, Foster Wheeler** and **Rolls-Royce**—and the company's joint exhibit features the work of all three concerns. The group is interested in the development of reactors in the 15- to 50-MW range for marine and aircraft propulsion or for small power stations. Present work is centred on the construction of a prototype British nuclear submarine, H.M.S. "Dreadnought," under an Admiralty contract. In conjunction with the A.E.A., Vickers N.E. has been associated with two research reactors, LIDO and NEPTUNE. Exhibits on Stand 145 include models of LIDO, an advanced gas-cooled reactor in a supertanker and a pressurized-water reactor in a large tanker. There are also models of steam/water separators and the chevron steam drier.

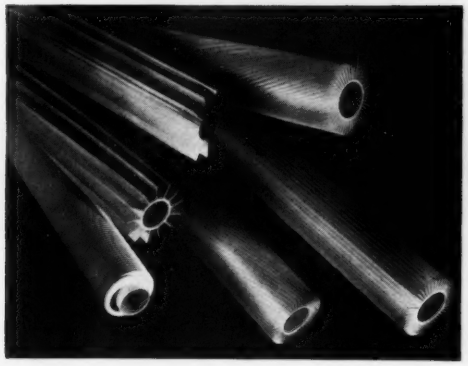
Rolls-Royce have themselves taken a separate stand in the British Section to illustrate the company's work on reactor control systems with especial reference to LIDO and NEPTUNE. Fine control gearboxes for both reactors are shown together with a model of NEPTUNE. Other exhibits include an analogue computer for investigating reactor control problems; a Herriott probe designed for the accurate measurement of liquid level in a reactor such as NEPTUNE and various shield plate materials.

Although not represented in the British Section, **Humphreys and Glasgow** are sending a team of engineers to the stand of their American associates, Alco Products. Humphreys and Glasgow hold world rights outside North America for the ALCO pressurized-water reactor based on the APPR which has now been in operation for 18 months. Humphreys and Glasgow offer to construct nuclear power plants of 5 to 20 MW(E) entirely engineered and manufactured in the U.K., based on Alco designs.

A model of the JASON research and training reactor can be seen on the stand of **Hawker Siddeley-John Brown Nuclear Construction.** This reactor, which is based on the Argonaut reactor of the Argonne National Laboratories, is particularly suitable for student training and research into reactor technology. The normal operating power is 1 kW with a maximum of 10 kW, giving a maximum flux of 1.5×10^{11} neutrons/cm^2 sec. The reactor has facilities for internal and external exponential experiments and is provided with a shielding tank and a thermal column with 16 beam holes for irradiation purposes.



Control and shut-off valve for use in radioactive gas circuits (de Havilland)



I.C.I. fuel cans in aluminium and magnesium alloys.

Further H.S.J.B. exhibits include a totally enclosed and electrically monitored area type flow meter, sections of fuel element cans and a control rod guide mechanism and an analogue computer of Hawker Siddeley Nuclear Power Co. design and **A. V. Roe and Co.** construction. This computer of advanced design and marked flexibility can solve nuclear kinetics problems including the evaluation of the effects of 11 delayed neutron groups present in heavy water reactor systems. Photographic exhibits feature a fuel element flask, a special grab equipped with a closed circuit television system for removing radio active cartridges and fuel elements, a gas bearing pump for gases and liquid metals at high temperatures, an experimental gas turbine and other items.

Design of the **de Havilland** stand is centred around presentation of the high temperature gas-cooled loop and associated equipment under construction for A.E.R.E. Harwell. Of prime interest is a model of PLUTO with H.T.G.C. loop in situ, sectioned to indicate the layout of the high temperature gas-cooled loop for testing a new type of ceramic fuel element. Perspective sectional drawings illustrate the details of the fuel element tube assembly and its associated disconnect equipment. An electrically energized rotative assembly mounted on self-acting gas journal bearings can be push-button started to demonstrate the action of this type of bearing. Design details of the small high-speed gas circulators incorporating self-acting gas bearings, under development for the H.T.G.C. loop, are illustrated by illuminated perspective sectional drawings. A full-size model of the circulator is also exhibited. Components of control and shut-off valves for use in radioactive gas circuits are individually mounted to indicate the details of their construction.

Fuel Cans

Nuclear fuel cans can be seen on at least three stands in the British Section. The most comprehensive display is on the **A.E.A.** stand, but **Fairey Aviation** are showing cans produced for Calder Hall whilst **I.C.I.** is featuring a 12-ft sample length of zirconium sheath made for A.B. Atomenergi in connection with the Swedish nuclear programme.

I.C.I. also manufacture Integron finned tubing for heat exchangers: nearly 400 miles of this tubing has already been ordered for the Berkeley and Bradwell stations.

Control Systems

Instruments for reactor control purposes displayed by **Elliott Bros.** include a power deviation meter, ND 301; multi-range linear d.c. amplifier, ND 311; ionization chamber supply unit, ND 271; shut-down amplifier, ND 281; log-amplifier and period meter, ND 261; and fine control rod amplifier, ND 122. The company has also built up a graphic panel featuring a whole range of control instruments for a power reactor.

A LIDO reactor control rack developed by **Ericsson's Telephones** can be seen on the **Solartron** stand.

General Radiological are exhibiting a complete control cubicle of the type they are making for Bradwell. Designed with particular attention to ventilation, safety and accessibility, the cubicle is fully instrumented. Among many other units on display are the following: A complete neutron counter withdrawal mechanism, as used during reactor start up, neutron sensitive ion chambers, foil counting equipment for flux scanning, annular ion chambers for flux plotting, and installed neutron monitors.

Ekco Electronics have also built a special reactor control panel to show typical examples of the company's nuclear instrumentation. Three new transistorized units are shown for the first time.

Designed for the control system of a high temperature gas-cooled reactor, the prototype gearbox shown by **H. M. Hobson** is employed to raise or lower

Graphic display panel showing typical instrumentation for nuclear power plant. Exhibited on the stand of Elliott Bros.

the control rod within the reactor core. Salient features include a magnetic clutch which, when released, will permit the rod to fall under gravity, for emergency operation. Other Hobson exhibits include a coarse control unit and master gearbox which form part of the Hobson A.E.R.E. control system for heavy water moderated and cooled reactors.

A novel test equipment is being exhibited by **Cambridge Instrument** in the form of a rod-speed recorder. Designed for testing the emergency shut-down arrangements of a reactor, the unit records on a chart the dynamic characteristics of a falling rod. The test cycle is entirely automatic.

A reactor safety equipment is being shown for the first time by **Mullard Equipment.** The enhanced reliability of the new system is due to the replacement of conventional electro-mechanical relays by transistor logic circuits to perform the necessary switching operations, and to the use of printed circuitry and advanced assembly methods. The extensive employment of transistors also reduces the power requirements of the system.

The function of the system is to initiate warning or shut-down conditions in the reactor plant when fault signals are received from instruments monitoring the significant parameters of the pile. To prevent a spurious shut-down the system also determines when a fault signal is due to the failure of a monitoring channel and not to a reactor abnormality.

Various control systems comprise the main body of exhibits on the **Plessey** stand. Particular emphasis is laid on burst slug detection for both gas- and water-cooled reactors. A flux scanning system employing an ionization chamber is also displayed. This equipment provides a rapid measurement of the neutron flux distribution within the core of a large gas-cooled reactor. A small neutron sensitive ionization chamber measures flux. The chamber is lowered through the core of the reactor on the end of a high-temperature flexible cable from a winding head, which is installed in a standpipe on the pile cap, the output of the chamber being passed via the winding head to a chart recorder. A number of winding heads are installed across the pile cap, each head being operated in turn from a control panel.

Sperry Gyroscope Co. are showing selected items of control and instrumentation equipment for nuclear power plants. The new Sperry reactor control-rod winding mechanism incorporates a number of special features designed to ensure safety, reliability and ease of operation and maintenance. The Sperry servo-driven control-rod position indicator has a presentation combining the general position of the control rod, its absolute position within 0.1 mm and a "tell-tale" indication of direction of control-rod movement and speed. An example is also shown of the recently developed range of d.c. "vernier" or stepping motors, a large version of which is incorporated in the reactor control-rod winding mechanism.

A company specializing in nuclear instrument installation, **R. Hutcheon Duthie and Son,** is represented by means of an illuminated display board showing photographs of instrument control panels and associated work that the company has undertaken.

Reactor Components

Fabrications by **A.P.V.** and castings by their associate company **A.P.V.-Paramount** are featured on a combined stand. A.P.V. have fabricated the aluminium core tanks for most of the British research reactors and some for overseas, and examples of tanks which they have made for DIDO, MERLIN and NEPTUNE type reactors are illustrated together with a display of weld samples and techniques. A.P.V.-Paramount show one of the reactor guide pan steel castings which the company is to supply for Hunterston nuclear power station and also lantern and plug castings in stainless steel for the Bradwell nuclear power station. In addition castings are shown in a series of corrosion and heat resisting materials for other nuclear energy projects.

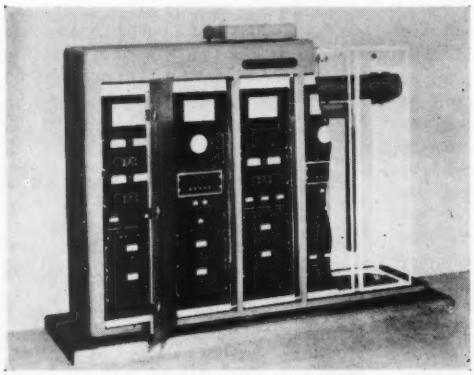
Hayward Tyler, a member of the Platt group, is exhibiting a sectioned model of a glandless motor pump unit. This unit comprises a single shaft rotating in two journal bearings within a pressure-tight casing. The upper part of the shaft carries the motor rotor, the pump impeller being at the lower end.

The wide range of filters developed by **Vokes** for nuclear engineering include the latest Absolute types, a feature of which is their extremely high dust retention efficiency with very low restriction characteristics. Lubricating and transformer oil filtration is catered for by a Vokes subsidiary **Stream-Line Filters.**

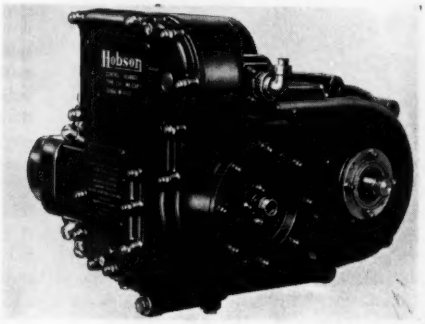
Radiation resistant lubricants can be seen on the **Shell** stand. The Shell APL oils and greases were first introduced eighteen months ago since when they have won wide acceptance.

Marston Excelsior, an I.C.I. subsidiary, is featuring examples of the company's nuclear engineering projects including light alloy pipework, heat exchangers, condensers, gas coolers and compressors. Other Marston exhibits include tube bundles associated with burst slug detection and a plate-type fuel element. One other I.C.I. company represented on the stand, **Amal,** is featuring a flow pack based on the construction of the Amal flame trap, as supplied to U.K.A.E.A.

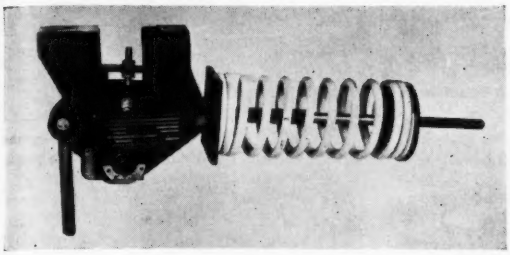
Reactor coolant and steam circuits are catered for on two stands. **Vokes Genspring** feature examples from their wide range of variable and constant



(Left) Reactor control cubicle designed and built by General Radiological.

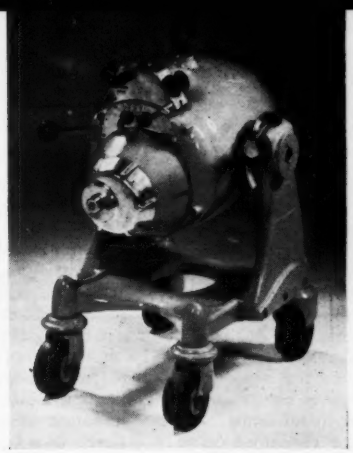


(Right) The type 336 control rod gearbox by H. M. Hobson incorporates a magnetic clutch which allows the rod to drop under gravity before being finally driven into the correct position.



(Left) Vokes Genspring M range constant support hanger.

(Right) Panatron industrial radiography equipment manufactured by Nuclear Engineering Ltd.



support hangers extensively used at Calder Hall and Chapelcross on the main CO_2 gas ducting. The new M range of constant support hanger is said to provide a more economical installation. **Aiton** are also showing their Mk. 2 Uniload support together with A type expansion fittings and corrugated pipework. Many exhibits on the Aiton stand are in model form. For advanced service conditions the company offer very thick wall piping in both carbon and alloy steel. One exhibit in 2¼% chromium/1% molybdenum alloy material illustrates a form of butt welding profile; another exhibit in carbon steel is sectioned to show the structure of a very heavy branch weld.

Talbot Stead Tube Co. is one of the companies represented on the stand of TI Nuclear Engineering. The company is showing a number of reactor components including breeder thermocouple guide tubes, fuel element support, restraint bar, charge plug and stainless steel tubes and flanges. Models of a control rod, restraint bar and charging standpipe assembly are also on display.

Another TI company, **Crane Packing,** is featuring PTFE in various forms together with gland packings and mechanical shaft seals. PTFE is used for some of the major components in a bellows pump developed by Crane for handling corrosive liquids. The gland packings include some designed for use with gases such as UHF_6 or hot CO_2. A 7-in. diameter shaft seal has been developed for hot CO_2 circulation fans.

From their range of valves designed for nuclear applications, **Newman Hender** are displaying forged steel globe and gate units, needle-type bellows-sealed and parallel slide valves with seal-weld flanges.

A great deal of research is at present being carried out by British companies into new metals for nuclear applications. The **Imperial Chemical Industries** stand is of great interest in this respect. Metals such as beryllium, vanadium and niobium can be used for fuel element manufacture whilst titanium is suitable for fabricating components in control rods and fuel charge/discharge machines. For fuel sheathing and structural components in boiling and pressurized water reactors alloyed zirconium is of considerable importance. Zirconium fuel element support brackets are being supplied for use at Berkeley. As a demonstration of their extensive capacity for the production of titanium I.C.I. are showing a 2-ton ingot.

The corrosion and heat resisting characteristics of nickel alloys have an important part to play in nuclear engineering. **Mond Nickel** and its associate, **Henry Wiggins,** are therefore featuring their world-wide service of technical information about the metal with particular reference to its role in nuclear applications.

Remote Handling

So far as remote handling is concerned there is much of interest in the British Section. Reference has already been made to the powered manipulator which can be seen in operation on the **G.E.C.** stand. Two special power-operated manipulators for the continuous remote handling of spent fuel elements from the Calder reactors are being featured by **Savage and Parsons.** After the exhibition these manipulators will be installed in the new fuel element pond being built by U.K.A.E.A. at Windscale. The manipulators are designed to transfer the 24 elements from each discharge basket one at a time and pack them into rail-borne skips, which are then submerged in water for periods up to six months, to allow short-lived activity to decay. The transfer operation takes approximately 30 minutes.

Two master slave manipulators are the main feature of the **Pye** stand. The lateral displacement mechanism, which is powered by an actuator, enables the slave arm to be displaced 30° with respect to the master arm through most of the index range. This gives increased coverage of the hot cell, and enables the operator to work either side of the centre line without moving himself from side to side.

A stereoscopic television camera, with pan and tilt, and two monitors, aids judgment of distance when viewing remotely. This is particularly useful when performing intricate operations within the cave when the operator cannot look through the zinc bromide window. A standard industrial camera, with a zoom lens and pan and tilt, gives a close-up view of dials and other objects within the cave. Pedals enable the operator to control lateral displacement, TV focusing and pan and tilt units, without taking his hands from the manipulator controls. Pye also show a CO_2 cooled reactor camera with a remotely controlled mirror on the head; this allows both forward viewing and right-angled inspection of the hot cell. Alternatively, a manipulator head can be fitted.

Radiation shielding glass is featured by **Chance-Pilkington Optical Works.** Specimen 3-ft polished plate glass, 1 in. thick, with densities of 4.3 g/cc. and 2.5 g/cc. is displayed on the company's stand. The 4.3 density glass is shown in both stabilized and unstabilized form. Stabilized glasses have their compositions amended to reduce the tendency to discolouration upon receipt of high doses of radiation.

The Model 7 master slave manipulator on the stand of **H. M. Hobson** has a handling capacity of up to 10 lb per arm. The design incorporates a system of delicate counter-balancing which, combined with maximum reduction of mass friction and lost motion, provides remarkably sensitive feel characteristics, a feature which makes this manipulator ideally suited for use in hospital and kindred laboratories where space limitations and mobility are essential considerations. Provision is made for the remote interchange of tongs.

Townson and Mercer feature a rigid glove cabinet developed to U.K.A.E.A. requirements, with exceptionally low leak rates for handling dangerous radioactive materials. The interior is lined with melamine resin and all joints are flooded and sealed with resin individually, after fabrication. Air locks, lighting, heating, and any number of glove ports can be fitted to these cabinets, which are normally available in two standard sizes. The cabinet is designed to take a motor pump and filter unit which embodies the standard Harwell radio-active dust filter, and maintains negative pressures of 1.5 cm W.G.

For less dangerous work, Townson and Mercer offer a collapsible flexible and welded glove cabinet with integral glove construction. This is extremely cheap and expendable and can be used at slight negative pressures for all normal handling of mildly dangerous materials. There is an integral air lock, and the whole top is transparent and can be opened with an airtight zip fastener for the insertion of really large pieces of apparatus. Handling tongs with interchangeable heads have been produced to a Harwell design: all the major working parts are either of stainless steel or heavily chromium plated.

A filter and fume removal unit specifically for dealing with air exhausted from glove box cabinets is exhibited on the **Vokes** stand. The company has also developed a mobile swarf collector operated by remote control.

M

Computers and Simulators

The past few months have seen the introduction of several new computers and data handling units for nuclear applications. Amongst companies represented in the British Section are: **Elliott Bros., Ferranti, Solartron, Rolls-Royce** and **Sunvic Controls.** The Elliott reactor simulator, ND.181, is now well established as a training device. The unit incorporates the analogue of a reactor system and is constructed from standard Elliott analogue units. These computing units are connected up in a manner to solve the reactor kinetics equations. Suitable outputs from this computer representing reactor power, reactor period, shut-off rod and control rod positions, reactivity, etc., are indicated or recorded on instruments on the control panel. The unit may be controlled manually or use may be made of two automatic control systems, one an on-off system and the other a proportional system. As in normal practice, trips are incorporated to shut down the reactor automatically should either the power level or period pass through preset limits.

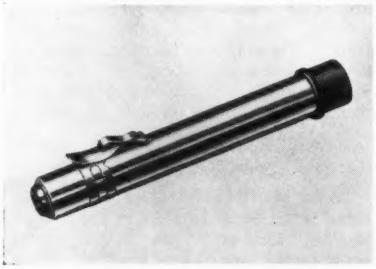
A display featuring the Mercury high-speed computer is the principal exhibit of **Ferranti.** Already seven of these computers have been sold for nuclear calculations. An autocode has now been devised for the machine to simplify the preparation of problems and shorten the time necessary for solution. The **Solartron** reactor simulator is represented at Geneva by a photographic display, although some units of the equipment are actually on show. **Rolls-Royce** are featuring their own analogue computer specifically designed for handling nuclear problems.

A magnetic memory storage drum intended for use with the burst slug computer being built for Berkeley is being exhibited by **Sunvic Controls** on the **A.E.I.-John Thompson** stand. The drum has a capacity of 500,000 binary digits. At Berkeley each unit will memorize the previous 48 counts from each of more than 400 channel groups. Another Sunvic development is a pulse height analyser which incorporates a ferrite core storage matrix and is largely transistorized.

Radiation Detection

A new hand and clothing monitor, type 1, has been developed by **E.M.I. Electronics.** Four large area scintillation counters with special dual scintillators are used to detect simultaneously both alpha and beta contamination on the hands. Separate meter indications are provided and a unique feature is that the final meter readings remain after the hands have been removed. These readings are cancelled when the next person begins testing. Background gamma radiation up to a level of 0.5 milliroentgens per hour is automatically cancelled during the operating period which can be as short as five seconds. Two probes attached to the sides of the main cabinet provide separate indications of both alpha and beta-gamma levels. As they may be used at the same time as the special hand counters it is possible to monitor three people simultaneously, thus greatly increasing the rate at which personnel can be checked for contamination.

Dosemeters of up to 500r can be found on the stand of **R. A. Stephen** whilst **Taylor, Taylor and Hobson** are displaying Kershaw dosemeters from 0.5r to 1000r for personnel protection. Large quantities of Kershaw quartz fibre electrostatic dosemeters have been supplied to the Ministry of Supply.

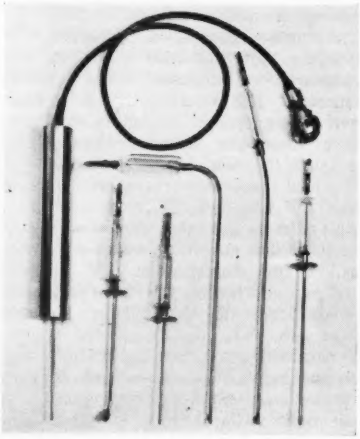


Taylor, Taylor and Hobson are featuring this 5r Kershaw dosemeter.

Isotope Developments 210 package monitor is used for checking the contents of cans, tubes, cartons of tablets, on high speed packaging lines. Incorrectly filled containers are automatically rejected. The measuring head incorporates a Geiger-Müller tube and a small beta source.

The latest wall thickness gauge by **Ekco Electronics,** the N563 gamma back-scatter gauge, employs transistors and printed circuit technique. It is designed for measuring the thickness of pipe walls or sheet materials where only one side is accessible. The N611 fluid density gauge is extensively used in industries where the product is in slurry form.

For measuring the concentration of uranium ore in a slurry flowing through a steel pipe **Electronic Instruments** offer a Vibron gamma-ray electrometer. This instrument is designed around the Vibron unit which replaces the conventional electrometer valve and enables very small direct currents to be measured accurately.



Display of needle counters introduced by 20th Century Electronics.

The EEL reflection microscope photometer shown by **Evans Electroselenium** is of interest to mineralogists in identifying unknown ores which the unit does by means of the reflectance method. The EEL blood cell counter is extensively used in health physics departments of A.E.A. establishments.

Hand and clothing monitor, type L.310 introduced by Mullard Equipment.

Radiation detectors made by **20th Century Electronics** are exported all over the world. At Geneva the company is showing a very wide range of units; enriched BF_3 proportional counters, fission chambers, ionisation chambers for reactor control, fast neutron counters in addition to Geiger Müller counters and photomultiplier tubes. 20th Century operate low temperature distillation plants for separation of boron 10 and carbon 13. A new range of needle counters for medical applications is also on show.

A reactor effluent monitor has been included in the **Plessey** display as an example of installed health instrumentation. The company is also showing a monitor for checking the radioactive contamination of liquid or solid foods and a gamma survey meter for measuring high intensity gamma dose rates in contaminated areas. The meter is calibrated from over three decades to 500 r/hr.

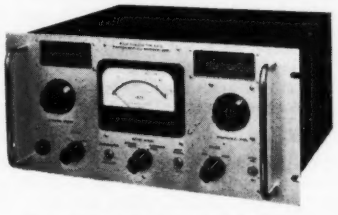
Another effluent monitor can be seen on the stand of **Fleming Radio.** It comprises a small transistorized ratemeter with an encapsulated Geiger-Müller tube. A radio-active air pollution recorder and a personal radiation monitor are also shown.

The **Avo** No. 1 radiation monitor is light, portable and self-calibrating. Battery-operated, it will measure χ β and γ radiation on a 5-in. log scale calibrated from 1 mr/hr to 5 mr/hr. Avo's hot spot monitor is a very light portable battery-operated instrument with a remote ion chamber for the measurement of radiation intensity in close proximity to high-level sources of β and γ radiation.

The L 310 hand and clothing monitor featured by **Mullard Equipment** has been designed in conjunction with A.E.R.E., Harwell. The six-bay equipment incorporates one pair of alpha hand units, one pair of beta-gamma hand units, an alpha clothing unit and a beta-gamma clothing unit.

There have been many developments in scintillation counting during the past decade and a large selection of organic scintillators is now available from the U.K. Two British companies are represented at Geneva. **Nash and Thompson,** for example, have developed methods of growing large crystals of anthracene, stilbene, diphenyl acetylene and p-terphenyl. The company also produces plastic scintillators in a base of either polystyrene or polyvinyl toluene and liquid scintillators.

Nuclear Enterprises (G.B.) are featuring the latest gadolinium and samarium loaded liquid scintillators as well as very large blocks of plastic phosphor. The NE5202 non-overloading amplifier has a gain of 50,000 and a recovery better than five microseconds for 100 times overload. A tritium counting installation incorporating NE5102 and NE5202 units permits liquid scintillator counting of millimicrocurie quantities of tritium at 0°C with an efficiency better than 30%. Nuclear Enterprises are also introducing a new equipment for large-scale radioactive tracer studies. Using short-lived or highly diluted radioisotopes, this equipment enables the flow patterns of materials in a process plant to be studied.



Type N.102 pulse analyser by Dynatron Radio.

Three Panatron industrial radiography units are featured by **Nuclear Engineering, Ltd.** The CR.500 and CR.5000 are intended for the inspection of iron and steel in the thickness range ½ in. to 8 in., the sources having gamma energies of up to 1.5 MeV. The Pantasafe II is designed for the safe storage of radioisotopes. Nuclear Engineering, Ltd., also specializes in chemical irradiation and a full-size unit is displayed on the stand.

Recorders

The main item of interest on the **George Kent** stand is the Multelec Mk. 3 high-speed electronic strip-chart recorder for such applications as temperature, millivoltage, reactor power-level measurement (both linear and logarithmic); reactor power-drift measurement; gamma health monitoring; gamma activity in fluid circuits; control arm or rod position and analogue-computers. One version of the instrument is a multi-point scanner with a new presentation system: it is shown recording the readings from 90 individually scanned points on a single chart, with clear identification of each reading.

The latest addition to the versatile Commander range, the Kent-Barton non-mercurial meter for flow, level and specific gravity, etc., is also on display.

A new multi-point thermocouple temperature recorder, which provides a permanent printed record of the temperature being measured from any one of up to 500 points in a reactor core, the time at which the reading was taken and the channel identification, is being introduced by **Savage and Parsons.** The recorder consists, basically, of two units —one contains a precision voltage supply for the thermocouples, and the printing head, motor-driven slidewire and servo equipment, and the other unit is an extension box housing 50 thermocouple connections, selector switching and provision for a "cold junction oven."

Cambridge Instrument have included their DE electronic recorder-controller, the Mk. 3 electrochemical dissolved oxygen analyser, a CO_2 purity indicator and a new centre-lined controller amongst the range of products on their stand.

Ancillary Units

As might be expected, there is a profusion of basic research instruments such as oscilloscopes and pulse generators. **Dawe Instruments'** new 412B pulse generator is a general purpose unit having a wide recurrence frequency range from 25 c/s to 100 kc/s with a pulse width continuously variable from 0.3 microsecond to 60 milliseconds. It may be used for checking the performance of linear amplifiers, scaling units and for setting discriminator bias levels.

Ultrasonics is now being used for cleaning hand tools and other equipment retrieved from "hot" areas. **Mullard Equipment** are showing an ultrasonic cleaning equipment with a tank driven by a 20 kc/s magnetostriction transducer system energized by a 2kW generator. Mullard's low power ultrasonic drill is also being used for cutting holes and patterns in fuel elements.

Labgear are showing on the **Pye** stand a complete range of nuclear counters and times together with health monitoring and warning instruments designed for use with irradiation units. Also represented on the Pye stand are **Unicam** (spectrophotometers and a high temperature powder camera) and **W. G. Pye** (test equipment).

A new wide-band general purpose oscilloscope, type WM7, designed to meet the full specifications of the North American and other markets is being introduced by **E.M.I. Electronics.** The instrument's Y amplifier bandwidth extends from d.c. to 50 Mc/s (−3db), when a plug-in wide-band amplifier having a vertical sensitivity of 100 mV per cm is used. An alternative dual-channel beam switch plug-in unit gives a band width of d.c. to 25 Mc/s, with a vertical sensitivity of 50 mV per cm.

N.563 wall thickness gauge exhibited by Ekco Electronics.

The **Cossor** range of test equipments includes several double-beam oscillographs, associated camera units, a millimicrosecond pulse generator and other specialized units for laboratory work.

The requirements of nuclear laboratories have not been overlooked, and **Dynatron Radio** are featuring, on **Ekco Electronics** stand, a scanning pulse amplitude analyser, N.102, single-channel pulse analyser, N.101 transistorized scaler, 1287 A, and a 1036C coincidence unit.

Isotope Developments new 1700 scaler has automatic pre-set count and timing facilities. It includes a four-range ratemeter, a pulse amplifier, a stabilized high-voltage supply up to 2 kV, a simple pulse analyser, and power supplies for an external quench unit or pre-amplifier. In conjunction with a Geiger-Müller tube or scintillation counter, it forms a self-contained counting equipment.

From their range of precision balances, **Stanton Instruments** have included free-swinging and aperiodic units with partial and full-weight loading, single pan models and thermo-recording balances.

The S. 200 precision constant-temperature bath featured by **Townson and Mercer** has an accuracy of ±.001° C at 40° C. With its aid radioactivity can be measured calorimetrically.

The pressure amplifiers shown by **Negretti and Zambra** give remote readings of small pressure fluctuations in process plant. The company has also developed a gap measuring probe which embodies a transmitting capsule built up from diaphragms of N. and Z. manufacture.

Publications

Three publishing houses associated with the nuclear industry are also taking space in the British section. **Rowse Muir Publications** are on stand 143; **Pergamon Press** can be found on stand 137, whilst *Nuclear Engineering's* own stand is 129. Visitors who require information about the journal or any aspect of nuclear engineering, including the sources of supply of materials and equipment are invited to call at stand 129. Copies of the first three titles in the Nuclear Engineering Monograph series will be on display together with details of the next three titles in the series which are scheduled for publication during October. In addition there will be a representative selection of the range of specialized technical journals published by **Temple Press Limited,** the proprietors of *Nuclear Engineering.*

Patents Reviewed

These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).

B.P. 790,389. Fuel elements for use in nuclear reactors. I. H. Morrison. To: U.K. Atomic Energy Authority.

It has been found that magnesium and magnesium alloy as sheath material have the undesirable property of cumulative stretching owing to their large coefficient of thermal expansion coupled with softening and deformation under pressure (on cooling, friction forces prevent free contraction). This can be overcome by providing concavities in the fuel element into which fit indentations made in the sheath, e.g. by circular grooving of the fuel rod and pressurizing the sheath on the rod to fill the grooves.

B.P. 790,474. Means and method of treating water. P. A. F. White, A.A. Smales. To: U.K. Atomic Energy Authority.

Removal of small quantities of radioactive substances from contaminated water (residual radioactivity of aqueous effluent) is effected by a precipitate formed from tannic acid and a soluble calcium compound under alkaline conditions. This is maintained in the water for a period of 3 to 5 hours, and the precipitate is then separated.

B.P. 790,688. Heat transfer arrangements. D. A. Boyland. To: General Electric Co., Ltd.

In gas-cooled nuclear thermal reactors, the usual arrangement is the introduction of the cooling gas through a chamber connected with the ends of the channels containing the fuel elements on one face and collecting the heated gas from a similar chamber at the opposite face. The gas is driven through the channels by a blower and the difficulties in practice arise out of (1) the great resistance to gas flow in the channels; (2) the attack of the cooling fins by the coolant gas; (3) the energy consumption by the blower and the costs and weight of the surrounding pressure vessel to withstand high gas pressures. These difficulties are overcome by the arrangement of the path of the coolant gas transversely to the fuel elements, e.g. by ducts for the flow of coolant on each of two opposite sides of the fuel elements, one serving as the inlet, the other as an outlet, so that the coolant flows across between the transverse cooling fins. The flow may be controlled by decreasing the cross-section of the inlet duct in the direction of flow, and at the same time increasing that of the outlet.

B.P. 790,991. Uranium-niobium alloys. P. C. L. Pfeil. To: U.K. Atomic Energy Authority.

Alloys of uranium and niobium as fuel elements in nuclear reactors (containing from 0.1 to 6% by weight niobium, the remainder being uranium) show improved corrosion resistance and increased hardness compared with pure uranium. If the percentage of niobium is increased (over 6 to 20%) then the phase of uranium is stabilized down to relatively low temperatures. Such alloys may undergo repeated thermal cycling without change of structure. If a very high percentage of niobium is present (at least 60, preferably 75%) and the remainder is uranium highly enriched with U^{235} or U^{233}, or both, and/or Pu^{239}, the alloys may be used in fast fission nuclear reactors, the niobium serving as a diluent for the fissile uranium. Niobium raises the melting point from 1,130°C to 2,550°C according to its percentage in the alloys.

B.P. 791,011. Nuclear reactors. W. E. Dennis, P. A. Lindley. To: General Electric Co., Ltd.

In gas-cooled nuclear reactors the avoidance of mechanical abrasion in the fuel channels of the reactor core during charging and discharging operations is one of the problems to be solved. Other problems are to avoid chemical attack on the moderator by the gas with or without mass transfer of moderating material, and to overcome the effects of radioactive contamination which would render the channel unsuitable for further use. The problems have been solved by housing one or more fuel elements, within a tubular member constituting a lining or part lining for a channel, and forming, together with the fuel element, a replaceable unit. The gas then flows through the tubular member to abstract the heat from the fuel elements which are spaced away from the inside wall of the member which may be made of moderating material.

B.P. 791,100. Uranium fluoride separation of plutonium and fission products from irradiated uranium. To: Atomic Energy of Canada, Ltd. (Canada).

Uranium tetrafluoride and/or uranium trifluoride is added to neutron irradiated uranium, which is then heated in an inert atmosphere to a temperature of 1,135° to 1,350°C to melt the uranium. The uranium phase and the salt phase are separated by distillation or by gravity separation. For 100 parts of uranium 1 to 50 parts of uranium tetrafluoride may be used.

B.P. 791,121. Production of niobium. A. E. Williams, P. B. Eyre, J. Jackson. To: U.K. Atomic Energy Authority.

To initiate the reaction, potassium niobium fluoride, in admixture with a small stoichiometric excess of sodium metal (10%), is heated in an inert atmosphere. After conclusion of the reaction, the products are maintained at a temperature (1,100°C) above the boiling point of sodium, to distil off the excess of that metal, and of any potassium. The products, after cooling, may be crushed and leached with water, to remove soluble salts.

B.P. 791,941. Generation of electrical power. To: U.K. Atomic Energy Authority (U.S.A.). (Date of application in U.S.A. 3-7-45.)

Uranium in the form of wires or thin rods is disposed within cylinders of copper, aluminium, beryllium, carbon, lead, bismuth or other electrical conductor of low absorption cross-section but separated by an insulating space (vacuum or quartz, glass, mica, polystyrene, etc.). The cylinders have a thickness of about 1 mm, just enough for the capture of beta particles. Both the conductive cylinders and the uranium rods are electrically interconnected. After deduction of energy losses by ionization, a voltage remains, usable either directly where high voltages and low currents are suitable, or for use with the Van De Graaf generator.

B.P. 792,071. Scintillation materials and methods of making same. To: Armour Research Foundation (U.S.A.).

It has been discovered that the scintillation characteristics of a single crystal scintillator can be closely approximated by an autogeneously bonded polycrystalline compact made from a compacted mass of microcrystals of a host compound, permitting propagation of energy derived from nuclear radiation and an activator capable of fluorescence under the influence of such energy. It is not essential, as previously thought, to have a completely regular orientation of the host crystal ions as in the large single crystals hitherto used as scintillation phosphors. The compact is made of sodium iodide as host compound and 0.005 to 1% by weight of thallium interspersed therein as activator.

B.P. 792,113. Nuclear reactors. To: Stichting Reactor Centrum Nederland (Netherlands).

The reactor operates with a mixture of fissile material and heat carrying material (moderating material) circulated continuously through the reaction zone and a separate cooling zone. The mixture is formed of a powdery mass which passes downwards through the reaction zone under gravity, but is transported upwards through the cooling zone by fluidization caused by injection of gas. The fluidized mass should have a density only 20% (and preferably only 10%) less, than that of the unfluidized mass. The separation of the fluidizing gas from the mass at the top of the cooling zone is effected by gravity only. In order to keep the difference in density as low as possible, resistance to flow must be kept small by the largest possible cross-sections of all channels, lines and ports. The fluidizing gas should have a small neutron capture cross-section, e.g., oxygen carbon dioxide, carbon monoxide, helium. The heat carrying material (Bi_2O_3; MgO; SiO_2; $MgSiO_3$; $ZrSiO_4$; MgP_2O_7) may also contain breeder material, e.g., uranium-238 or thorium, particularly their oxides and carbides. The reactor may be homogeneous but may also contain the moderator as a stationary mass in the reaction zone.

B.P. 792,114. Nuclear reactors. To: Stichting Reactor Centrum Nederland. (Netherlands.)

When a reactor is operated with a mixture of fissile and heat-carrying material, circulating continuously through the reaction zone, and a separate cooling zone, certain particle sizes are to be preferred in consideration of the techniques of fluidization and heat transfer. The size of the particles should be between 50 and 300 microns with an optimum of approximately 175 microns. Their porosity should permit escape of any gaseous reaction products formed in the particles. The heat-carrying material will be constituted by chemically non-reactive elements with a neutron capture cross-section smaller than 0.1 barns per atom (bismuth, magnesium, lead, phosphorus, silicon, zirconium and/or aluminium or compounds of these elements oxides). The mixture is prepared from sintered baked or cemented aggregates of smaller particles of heat-carrying material soaked in a solution containing fissile material.